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AN EVALUATION OF THE TOTAL QUALITY MANAGEMENT  
IMPLEMENTATION STRATEGY FOR THE ADVANCED SOLID  
ROCKET MOTOR PROJECT AT NASA'S MARSHALL SPACE  
FLIGHT CENTER

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(NASA-TM-103533) AN EVALUATION OF THE TOTAL  
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# Glossary of Terms

ABMA	Army Ballistic Missile Agency
AEDC	Arnold Engineering Development Center
ASI	American Supplier Institute
ASRM	Advanced Solid Rocket Motor
DoD	Department of Defense
EM	Engineering Management
ET	External Tank
GOCO	Government Owned—Contractor Operated
I&PS	Institutional and Program Support
JSC	Johnson Space Center
KSC	Kennedy Space Center
MA	Management Announcement
MESA	Marshall Scientist and Engineers Association
MMI	Marshall Management Instruction
MSFC	Marshall Space Flight Center
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NET	NASA Employee Team
NMI	NASA Management Instruction
OMB	Office of Management and Budget
OPM	Office of Personnel Management
PDT	Product Development Team
QFD	Quality Function Deployment
R&D	Research and Development
RSRM	Redesigned Solid Rocket Motor (post- <i>Challenger</i> term)
S&E	Science and Engineering Directorate
S&MA	Safety and Mission Assurance (formerly SRM&QA)
SPC	Statistical Process Control
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor (pre- <i>Challenger</i> term)
SRM&QA	Safety, Reliability, Maintainability, and Quality Assurance
SSME	Space Shuttle Main Engine
TQM	Total Quality Management
TVA	Tennessee Valley Authority





An Evaluation  
of the Total Quality  
Management  
Implementation  
Strategy for the

## **Advanced Solid Rocket Motor Project at NASA's Marshall Space Flight Center**

### **Objective**

This document is an evaluation of the National Aeronautics and Space Administration's (NASA's) Marshall Space Flight Center (MSFC) strategy to implement Total Quality Management (TQM) in the Advanced Solid Rocket Motor (ASRM) Project. TQM is the application of quantitative methods and human resources operating in a supportive cultural environment to continuously improve and control product quality and performance of the enterprise. The external and internal environments at MSFC will be analyzed for their effects on the ASRM TQM strategy. Organizational forms, cultures, management systems, problem-solving techniques, and training will be assessed for their influences on the implementation. Literature

searches and surveys will be the basis for determining management and employee expectations and perceived status of TQM, and to correlate widely accepted philosophies to the observed strategic direction.

This analysis is intended to provide a better understanding of how MSFC's approach to TQM evolved to its current form. The influence of ASRM's effort will be assessed relative to its impact on mature projects as well as future projects currently awaiting "new start" approval. Recommendations will be offered for changes and/or additions to the current strategy that would make it more effective as a long range, continuous improvement program. ■





# Introduction

In the late 1950's the United States and Russia were in a race that would drive technology beyond realms imaginable. The goal was to be the first country to put an object in orbit about the Earth. On October 4, 1957, the Russians achieved this goal with the launch of Sputnik I, setting the stage for the great space race—landing a man on the moon.

During this time frame the U.S. decided a dedicated civilian government agency was needed to spearhead such an effort. It was partially derived from an organization called NACA (National Advisory Committee for Aeronautics), recognized as the world's premier aeronautical research organization since 1915. NACA was instrumental in testing remarkable flying machines in the 1920's, 1930's, and 1940's, supporting the country's wartime needs. The NACA era ended on October 1, 1958, with the creation of the National Aeronautics and Space Administration (NASA). NASA's first endeavor was the X-15 aircraft.<sup>1</sup>

Several NASA field and research centers were established throughout the U.S. over the subsequent years. MSFC was established on the Army's Redstone Arsenal near Huntsville, Alabama, on July 1, 1960. Its primary charter was to provide the propulsion systems for manned spacecraft. The MSFC charter was partially influenced by the existence of facilities, personnel skills, and contributing organizations in the geographical area. The Army Ballistic Missile Agency (ABMA) was in post-war operation at Redstone Arsenal, performing much of the nation's development on large rocketry. The scientists who led Germany's V-2 rocketry program during World War II had been located at Redstone to work on America's spacecraft systems, including propulsion, avionics, guidance, navigation, and structures. As MSFC became chartered, the German engineering leader, Wernher von Braun, became MSFC's first director, and the MSFC work force and facilities were transferred from the ABMA. Charter members of the ABMA transition who were interviewed discussed at length those exciting times, concluding that the MSFC culture became a composite of NACA, ABMA, Wernher von Braun, German scientists, and other factors.

MSFC developed progressively larger propulsion systems over the next few years that led to the space-

craft that carried man to the moon—the Saturn V rocket. It was an all-liquid propellant, expendable rocket with a crew capacity of three and a payload capacity of 250,000 pounds to low-Earth orbit, with a 105,000-pound capacity on a lunar trajectory. MSFC engineers and scientists designed and manufactured the first prototypes and flight vehicles at MSFC. On July 20, 1969, the ultimate goal was realized with Neil Armstrong taking the first step on the Moon.

During this time frame the U.S. was enjoying the post-World War II era with its manufactured goods deemed “best in the world”.<sup>2</sup> Federal funding was readily available, very few federal rules and regulations existed for NASA, and the American people were united in the effort to make the U.S. the leader in space exploration. However, during the late sixties and early seventies the U.S. was involved in a military conflict in Vietnam which was consuming large amounts of federal dollars. The focus of American politics shifted from an already won space race to the Vietnam conflict. While NASA wanted to continue space exploration (Skylab, Moonbase, and Mars Missions) at an accelerated pace, federal funding and support for the space program was diminishing. Congress felt that a space program was needed since its benefits had greatly enhanced life on Earth, but funding was becoming more difficult to allocate. For these reasons, Congress directed NASA to develop a low-cost vehicle that was more versatile than the Saturn V and could provide a routine access to space.

NASA responded by designing the space shuttle which consisted of a reusable orbiter (much like an airplane) that could carry the crew and payload, and used a two-stage propulsion system — the space shuttle main engines (SSME's) and the solid rocket boosters (SRB's). The SSME's are engines fueled by liquid hydrogen and liquid oxygen which is stored in the external tank (ET). The SRB's consist of solid rocket motors (SRM's) which are fueled by solid propellant. Until the Space Shuttle Program, manned vehicles had not used solid rocket propellant due to its inability to be tested before use and to be shut down in the event of in-flight problems. All components of the space shuttle, with the exception of the ET, are reusable (Appendix A). The Space Shuttle Program was originally planned to

provide 60 flights a year at program maturity. Capability was finally established at 24 flights per year. The funded manifest through year 2000, almost twenty years after the first flight, actually plans for less than 12 flights per year.

On April 12, 1981, the first space shuttle roared off the pad for a two-day mission. During the next five years, 24 missions would be flown with few problems. However, the space shuttle was not approaching the flight rate promised Congress, and cost overruns had existed since the outset of the program. Schedule and budget pressures were mounting, and NASA was finding it difficult to meet the goals of the Space Shuttle Program.

On January 28, 1986, after many delays, the Space Shuttle *Challenger* (Mission 51-L) was poised to lift off. There was much concern expressed by both NASA and Morton Thiokol, Inc. (SRM contractor) engineers over the unusually cold weather (below freezing) at Kennedy Space Center (KSC). The experience base relative to the O-rings (seals), where the SRM segments were joined (field joints), did not include data on retention of hot gases at temperatures below 40 degrees Fahrenheit.

The decision was made to launch and 73 seconds into the flight, the entire *Challenger* vehicle was lost in an explosion. All seven astronauts on board were killed. This brought the Space Shuttle Program to a complete halt until the cause could be determined and corrected. A Presidential Commission was appointed. Four months later, it reported that the SRM joint leak was the cause of the accident and that the joint required redesign. It took NASA two and one-half years to redesign, test, and certify the new joint, comply with the other recommendations offered by the commission, and return to flight.<sup>3</sup>

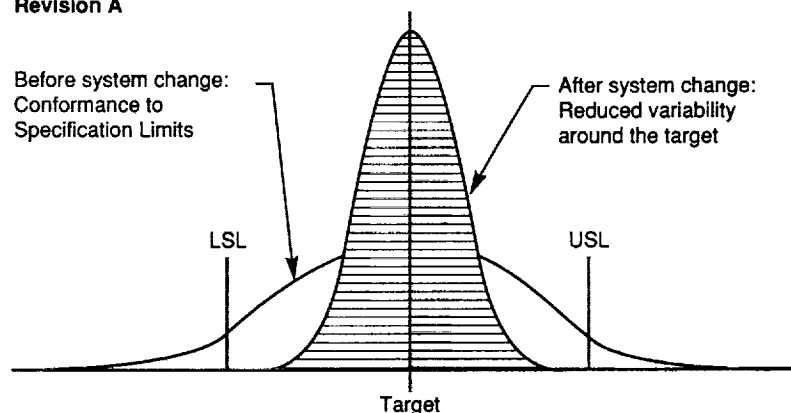
Another issue that surfaced out of the *Challenger* investigation was the concern of having only one contractor and production site as a source for the SRM. NASA was directed to develop an alternate SRM source that would deliver an advanced solid rocket motor (ASRM) with enhanced safety and payload capability. NASA responded by issuing a Request for Proposal for an ASRM to be manufactured at a Government Owned—Contractor Operated (GOCO) facility. The site for the GOCO facility was a partially completed, abandoned Tennessee Valley Authority (TVA) nuclear facility located near Iuka, Mississippi, called the Yellow Creek site. MSFC awarded a con-

## Redesigned Solid Rocket Motor Enhancement Program

### Technical Plan Revision A

Before system change:  
Conformance to  
Specification Limits

After system change:  
Reduced variability  
around the target



**Thiokol** CORPORATION  
SPACE OPERATIONS  
P.O. Box 707, Brigham City, Utah 84302-0707 (801) 863-3511

Figure 1

tract for ASRM production and facility development in May of 1989 to the Lockheed/Aerojet team.

The ASRM project is MSFC's most recent program. Starting a project of this magnitude (over \$2 billion in the next ten years) under current economic conditions is difficult. Developing a second source for a space vehicle is not a common practice. This program continues to meet opposition because hundreds of millions of dollars were spent improving the Thiokol Corporation redesigned solid rocket motor (RSRM). It has been improved to the extent that it is a competitor. It offers virtually the same product as the ASRM (less the performance gain) and is aggressively pursuing a program of reduced variability (fig. 1, page 4). In strategic business terms, statistical process control and other TQM-related elements are being used by Thiokol as "preemptive measures" to stop the competition before it starts.<sup>4</sup> To further complicate the issue, a NASA commission on space goals recently recommended that NASA decrease its dependency on the space shuttle by placing more emphasis on unmanned vehicles, some of which do not use solid propellant technology.<sup>5</sup>

From the beginning of the Space Shuttle Program (1969 to the present day), NASA funding and increases to funding have been difficult to obtain. With budget deficits, Savings and Loans bailouts, other domestic problems, foreign competition, and a war in the Middle East, it has become imperative for companies and government agencies to increase productivity and quality while reducing or maintaining cost. Most companies that have survived the suppressed economic environment implemented some form of "TQM" or "Continuous Improvement" program. Experiencing the same pressures as other companies/government agencies, MSFC management realized that it must also do the same.

The current atmosphere is one in which the old way of doing business could result in the cancellation of the ASRM Project. The use of TQM principles on the ASRM Project is essential for survival. Program success would serve as a testimony to other projects and organizations that TQM works, provide an example of a "petunia in the onion patch," (fig. 2, page 5) and begin a culture change at MSFC. ■

## The Onion Patch Strategy

What can be done when your company's top managers are not quality leaders and champions? When you are a lone quality champion without the support of top leadership – a "lonely little petunia in an onion patch"?<sup>23</sup> In general, the onion patch strategy is: "Think big, but stay close to your roots." Select improvement efforts within your span of control—but select improvements that capture the attention of people at least two links up in the chain of command. Look for projects with "big dollar" implications. For example, projects that reduce waste or rework, or increase sales or revenue. Concentrate your efforts on achieving the kind of results that the others, even the skeptics, will respect. Include other people in your efforts. Include even more people in the sharing of credit for a successful job. Build a network of believers and supporters while you make real improvements in the system.

Sometimes you will have direct supervisory responsibility over people involved in improvement efforts. If so, shield them from outside pressures so that they can continue the work of improving quality.

Be patient and persistent. If you succeed you may create opportunities to introduce the wider implications of quality to higher and higher levels of the organization. Meanwhile, prepare for any opportunities. Be ready to pounce when a mover and shaker asks for information or suggestions. Have at hand copies of books, articles, or videotapes of various lengths that are suitable introductory materials for your managers.

Have prepared an introductory presentation that is flexible enough to fit time slots ranging from 15 to 90 minutes. Have your presentation rehearsed and ready to go. Include, among your presenters, hourly operators who have become zealots for the new way. They need not be slick or articulate. Their excitement will be eloquence enough.

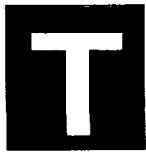
Identify the most common questions or objections and be prepared to respond to them. Figure out ways to persuade your managers to hear the quality leaders speak. Compile success stories. Prepare them in a "picture book" format that is easy to follow and loaded with graphics. Ask the resisters to help out on some quality activity.

The onion patch transformer must keep in mind that his or her efforts should always be geared to getting the attention of top management, educating them, and making believers and champions of them. Without their eventual buy-in, all of your transformation efforts will wither on the vine.

Reprinted from *Quality Progress*, July 1988, "Beginning the Quality Transformation, Part I," by Peter R. Scholtes and Heero Hacquebord.

Figure 2





## TQM—Background and Definition

TQM is the application of quantitative methods and human resources operating in a supportive cultural environment to continuously improve and control product quality and performance of the enterprise. Accepted TQM elements will be used to define TQM in this section. The background of TQM and the evolution to its current form will be discussed.

The genesis of the government-wide interest in TQM arose from the Office of Management and Budget (OMB) draft circular shown in Appendix B. If the draft circular had progressed to a directive, each government agency's compliance would have been required. Consequently, the OMB would have been obligated to provide funding to each agency to study, plan, and implement effective TQM programs. The draft never became a directive and has since been withdrawn. It appears that there is no current polarizing force championing a top-level government-wide requirement to implement TQM.

In response to the OMB draft circular, NASA Headquarters issued NASA Management Instruction (NMI) 1270.2 shown in Appendix C. MSFC developed Management Announcement (MA) 1150.1A (Appendix D) and readily established an Executive Steering Council, tasking it to study different programs, approaches, and training courses for a TQM program. The membership of the council appears to be at a sufficiently high level to assure support by upper management. The ultimate goal of the Executive Steering Council is to produce changes resulting in the type of management that generates the increased quality, productivity, and customer awareness essential in the space program.

According to Joseph M. Juran, all quality improvement takes place project by project and in no other way. Project is defined as a problem scheduled for solution — a specific mission to be carried out. The first step in mobilizing for the projects collectively is to establish a quality council or committee to launch, coordinate, and institutionalize annual quality improvement. If no such council is in existence, the top managers should create one. Upper managers should personally become the leaders and members of the senior quality council.<sup>6</sup> Therefore, it appears that the creation and charter of the Executive Steering Council was on target.

TQM, a phrase coined by the Japanese, is being promoted throughout the government as the panacea to bureaucratic, matrix, and other cumbersome organizational forms. TQM has potential, but management philosophy fads such as Management by Objectives, Zero Defects, and Quality Circles have come and gone at MSFC. Quality Circles, for example, in most industries and government agencies have failed because management was confused over the purpose of this management technology. Managers were generally in search of "a way to fix" problems and discovered Quality Circles. Accounts were heralded of improved employee morale and true involvement. Confusion about the purpose of Quality Circles (and eventually their failure) began as both industrial and government managers tried to increase participation without releasing control. The groups chosen for Quality Circles were eventually only allowed to work on problems selected by managers. Misuse of a management technology will fail (be a fad).<sup>7</sup> If TQM is misused at MSFC, it will be the newest fad, and it will fail.

During interviews with ASRM management, it was generally recognized that the ASRM culture should be highly supportive of TQM. This culture would represent a shift from the MSFC culture. ASRM's contractors have already been directed to develop TQM approaches (Appendix E) and ASRM personnel will be expected to support the approach.

TQM program status is difficult to assess at the agency, MSFC and ASRM Project levels. During Quality Month (October 1990) activities, TQM was given ample consideration in public meetings and printed media at MSFC. In the three months following October, there were no TQM banners, posters, logos, or newsletters. Some visibility resulted from the annual MSFC calendar stating commitment to "Continuous Improvement" and a TQM Colloquium airing for two hours in January. This could be indicative of the infancy of the program. It could also mean that managers envision another management technology that is doomed for failure, or that the current TQM effort is not in earnest.

One way to evaluate the extent to which management is seriously attempting TQM is to gauge on-going activities relative to accepted definitions. There are of course as many definitions and vision statements for

TQM as there are businesses that are claiming to be implementing programs. MSFC and ASRM do not appear to have satisfied the basis for a TQM Plan—a clear and concise statement of fundamental organization-wide guiding principles for all employees. NASA and MSFC rely on NMI 1270.2 and MA 1150.1A to outline the TQM program's intent.

Some industries and government agencies use catch-all program descriptions as guiding principles. The Department of Defense (DoD) adopted the following definition of TQM:

Organized continuous process improvement activities involving everyone in an organization—managers and workers—in a totally integrated effort toward improving performance at every level. This improved performance is directed toward satisfying such cross-functional goals as quality, cost, schedule, mission, need, and suitability. Total Quality Management integrates fundamental management techniques, existing improvement efforts, and technical tools under a disciplined approach focused on continuous process improvement. These activities are ultimately focused on increased customer/user satisfaction.<sup>8</sup>

It is difficult to arrive at one definition that adequately covers the scope of such comprehensive endeavors. For example, the OMB draft circular defines TQM as:

A total, integrated organizational approach for meeting customer needs and expectations that involves all managers and employees and uses quantitative methods and employee involvement to improve continuously the organization's processes, products and services.<sup>9</sup>

An equally comprehensive description used by many companies would offer TQM as:

A systematic approach to productivity improvement using objective methods and all employees to continuously improve the quality of all products and services.<sup>10</sup>

According to MA 1150.1A (Appendix D) the MSFC definition states:

Continuous Process Improvement is a management philosophy/operating methodology totally committed to:

- a. Continuing improvement of all processes and products
- b. Satisfaction of internal and external customer needs
- c. Universal participation and teamwork.

The definitions generally use the same words as most TQM program descriptions. They do not, however, delineate the vision and how it will be achieved. More appropriate would be a detailed exposition of the means intended to employ and achieve a clearly stated vision. This would lead to an organizational culture that supports TQM and not a set of procedures written down and filed.

For purposes of analyzing TQM at MSFC and particularly in the ASRM Project, the models shown in figures 3 and 4 and the information shown in figures 5 through 7 will be used. Figure 3, "The Foundations of TQM" identifies the major elements of TQM, all operating in a supportive cultural environment. It highlights the fact that TQM is the application of quantitative methods and human resources to control and improve product quality and performance of the enterprise. Figure 4 (page 9), "The Westbrook Model for Engineering Management" acknowledges that there are many interactions and influences that naturally occur in the work environment. These influences can be external or internal, both affecting performance. The external environment has been the traditional focus involving the competition, paying customers, and governing

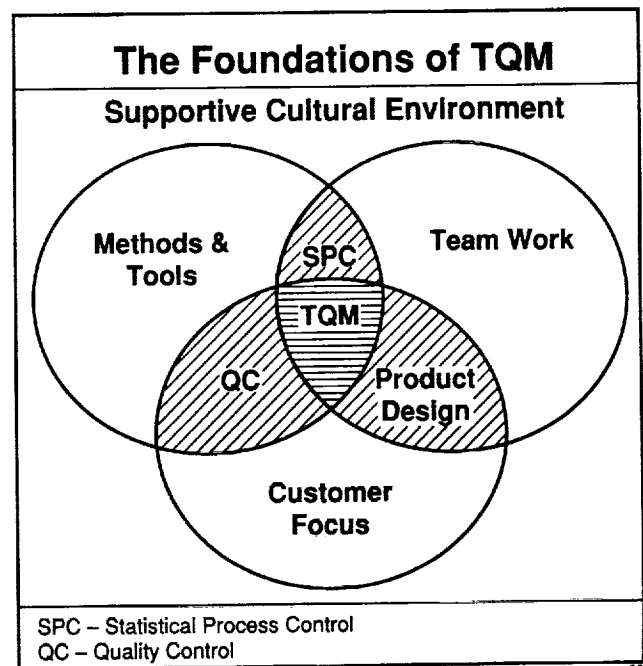
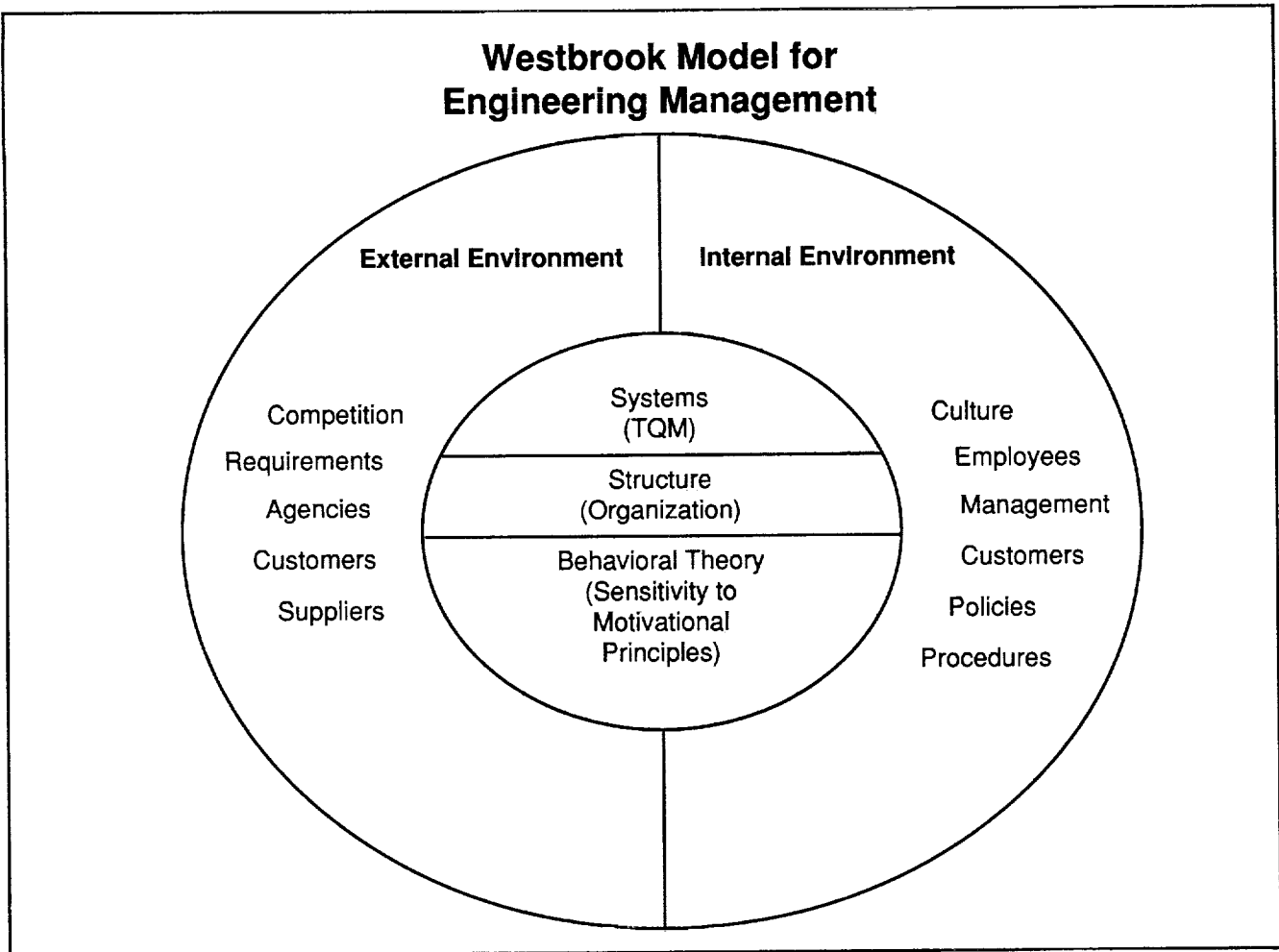


Figure 3



**Figure 4**

forces. The internal environment and its effects on the organization is the contemporary focus. Internal customers, culture, and employee involvement are a few of the major forces that affect performance when the internal environment is considered. At the core of the Westbrook model is the appropriate structure for organization, strategic plan, management systems (like TQM), and human resources management. Both models indicate that an internal environment must exist to attend the needs of the motivated individual in a Total Quality Company.

Figure 5, "TQM Definition" clearly distills and simply states the intent of the models shown in figures 3 and 4 and is offered as a potential ASRM definition of TQM principles. Figure 6 (page 10), "Typical Features That Identify Cultures" identifies the most significant aspects of a culture. Understanding what composes a belief system is the key to unlocking the changes sought through TQM. Figure 7 (page 10) compares Eastern and Western approaches to continuous improvement, according to the Japanese viewpoint. Kaizen (Japanese term for continuous improvement) usually

involves unsophisticated techniques while the Western approach usually features surges in technology, spurts of fast change and high investments.

<b>TQM Definition</b>
<b>Elements Required for a Total Quality Company</b>
<ul style="list-style-type: none"> <li>• Organization-wide focus on quality</li> <li>• Continuous improvement</li> <li>• Extensive use of measurement (statistics)</li> <li>• Cross-functional teams solving organizational problems</li> <li>• Increased sensitivity to and focus on customer needs</li> </ul>

**Figure 5**

Since the day an idea sparked the drafting of the now nonexistent OMB circular, many definitions and interpretations of TQM have been contrived. As a new management technology, if TQM is misused, it will be only a fad and it will fail. TQM principles for the

ASRM will be based on the clearly distilled and simply stated models. The information contained in figures 3 through 7 will be used as tools to analyze the NASA/MSFC/ASRM culture and TQM approach. ■

Typical Features That Identify Cultures	
<ol style="list-style-type: none"> <li>1. Language               <ol style="list-style-type: none"> <li>A. Jargon</li> <li>B. Metaphors</li> <li>C. Myths</li> <li>D. Stories</li> <li>E. Heroes</li> </ol> </li> <li>2. Ceremonies and celebrations</li> <li>3. Artifacts and symbols</li> <li>4. Patterns of Behavior               <ol style="list-style-type: none"> <li>A. Rites and rituals</li> <li>B. Behavioral norms</li> <li>C. Beliefs and values</li> <li>D. Subcultures</li> </ol> </li> </ol>	<p>Tends to attack intruders and defends existing culture</p> <p>Based on tradition and used to promote unity</p> <p>Silently sends a message about how welcome a new person or situation is</p> <p>The reinforcements to the way we act that counter change</p>

Figure 6

Features of Kaizen and Innovation		
	Kaizen	Innovation
1. Effect	Long-term and long-lasting but undramatic	Short-term but dramatic
2. Pace	Small steps	Big Steps
3. Timeframe	Continuous and incremental	Intermittent and non-incremental
4. Change	Gradual and constant	Abrupt and volatile
5. Involvement	Everybody	Select few "champions"
6. Approach	Collectivism, group efforts, systems approach	Rugged individualism, individual ideas and efforts
7. Mode	Maintenance and improvement	Scrap and rebuild
8. Spark	Conventional know-how and state-of-the-art	Technological breakthroughs, new inventions, new theories
9. Practical requirements	Requires little investment but great effort to maintain it	Requires large investment but little effort to maintain it
10. Effort orientation	People	Technology
11. Evaluation	Process and efforts for better results	Results for profits
12. Advantage	Works well in slow-growth economy	Better suited to fast-growth economy

Figure 7



# **A**dvanced Solid Rocket Motor Total Quality Management Status

To gain an understanding of how TQM is being implemented in the ASRM Project, one must also understand the culture, organizations, and systems at MSFC. This section will offer an explanation of the organizational forms and management systems for both MSFC and ASRM. Also, various surveys and studies recently completed that pertain to statusing TQM will be described.

The culture of MSFC is typical of aerospace organizations that are responsible for the design and manufacture of unique hardware for specific applications. The majority of managers are engineers or scientists with limited management training. According to statements made in the personnel interviews, most became motivated to "move into management to achieve a higher pay scale," not solely to manage people or projects. Career development at MSFC offers a limited number of paths, each with difficult crossover. Broadening activities are encouraged but not the lateral experience for horizontal growth.<sup>11</sup> It was stated in one interview that "most engineers are promoted into management based on their technical ability." New managers do not begin management training for the new assignment until months after the position is taken.

## **Organizational Forms**

MSFC is organized in a matrix form in the following areas: Staff Offices, Project Offices, Science and Engineering Directorate (S&E), Program Development, and Institutional and Program Support (I&PS) (fig. 8, page 12). The Staff Offices are the Center Director, Legal, Equal Opportunity Office, Comptroller, Personnel, Public Affairs, and Safety and Mission Assurance (S&MA), formerly Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA). Program Development formulates and develops new programs and is much like a Research and Development (R&D) organization found in industry. I&PS consists of Facilities, Procurement, and Information Systems.

S&MA provides oversight of the quality control and quality assurance activities at the manufacturing sites, vendors, suppliers, and for MSFC in-house projects. S&E provides design overview, technical support, technology development, and problem resolution

capability similar to engineering organizations in the commercial sector. The above mentioned organizations are support or R&D for the Project Offices.

The most identifiable matrix is the relationship to the Project Office by the S&E Directorate. The Project Office is product oriented (i.e., ASRM) and S&E is functionally oriented (i.e., Materials and Processes Laboratory). The Project Office consists of the Project Manager (and Deputy) and Project Control (resources and schedules) and is the primary MSFC interface to the contractor. S&E provides the project with a technical support organization, the Chief Engineer's Office. It serves as the technical interface between the project, contractor and S&E laboratories and is co-located with the Project Office personnel. However, the Chief Engineers report organizationally to the Deputy Director of S&E. Also co-located with the Project Office are Procurement, Facilities (ASRM only), and S&MA (fig. 9, page 13).

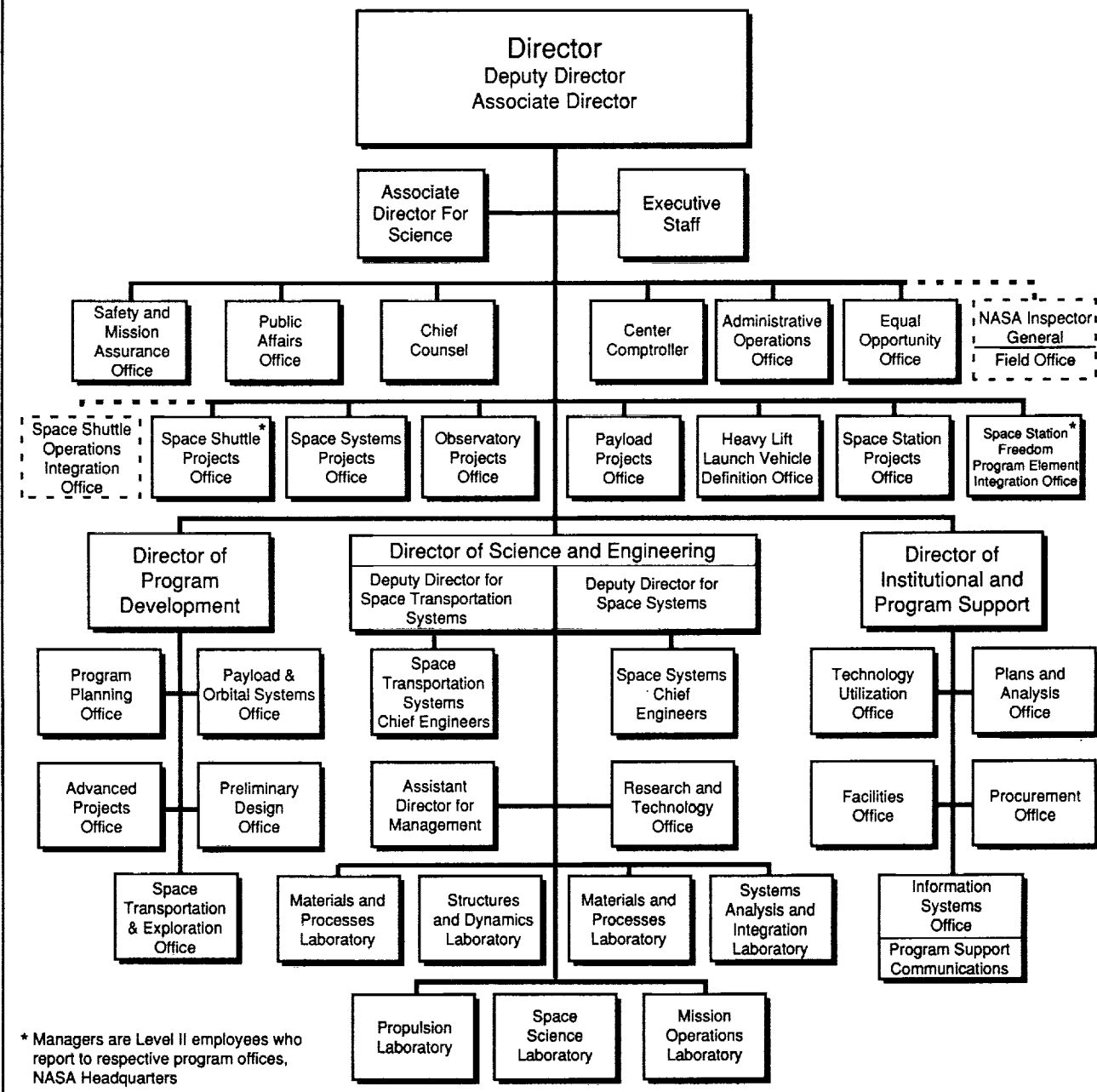
The ASRM Chief Engineers' Office is organized in three groups: (1) Systems Engineering and Integration, (2) Design and Development, and (3) Productivity Engineering (fig. 10, page 14). Each group has a chief and five (5) engineers.

The Systems Engineering and Integration group's primary functions are logistics, support equipment, integration of the ASRM with other space shuttle components, and interfacing with KSC and JSC operations. Their interfaces are primarily outside MSFC.

The Design and Development Engineering group's primary functions are to oversee the design, development, and test of all ASRM components (i.e., nozzle, case). They are organized by product and most of this group's functions are within MSFC.

The Productivity Engineering group assigns four engineers to work manufacturing, production and information systems and one to serve as the resident engineer at the Yellow Creek site. The three that work manufacturing and production are organized functionally in the following areas: Production/Facilities Integration, Tooling/Production Automation, and Manufacturing Processes. Like the Design and Development group, most of the Productivity Engineering group's functions are within MSFC.

National Aeronautics and Space Administration  
**George C. Marshall Space Flight Center**

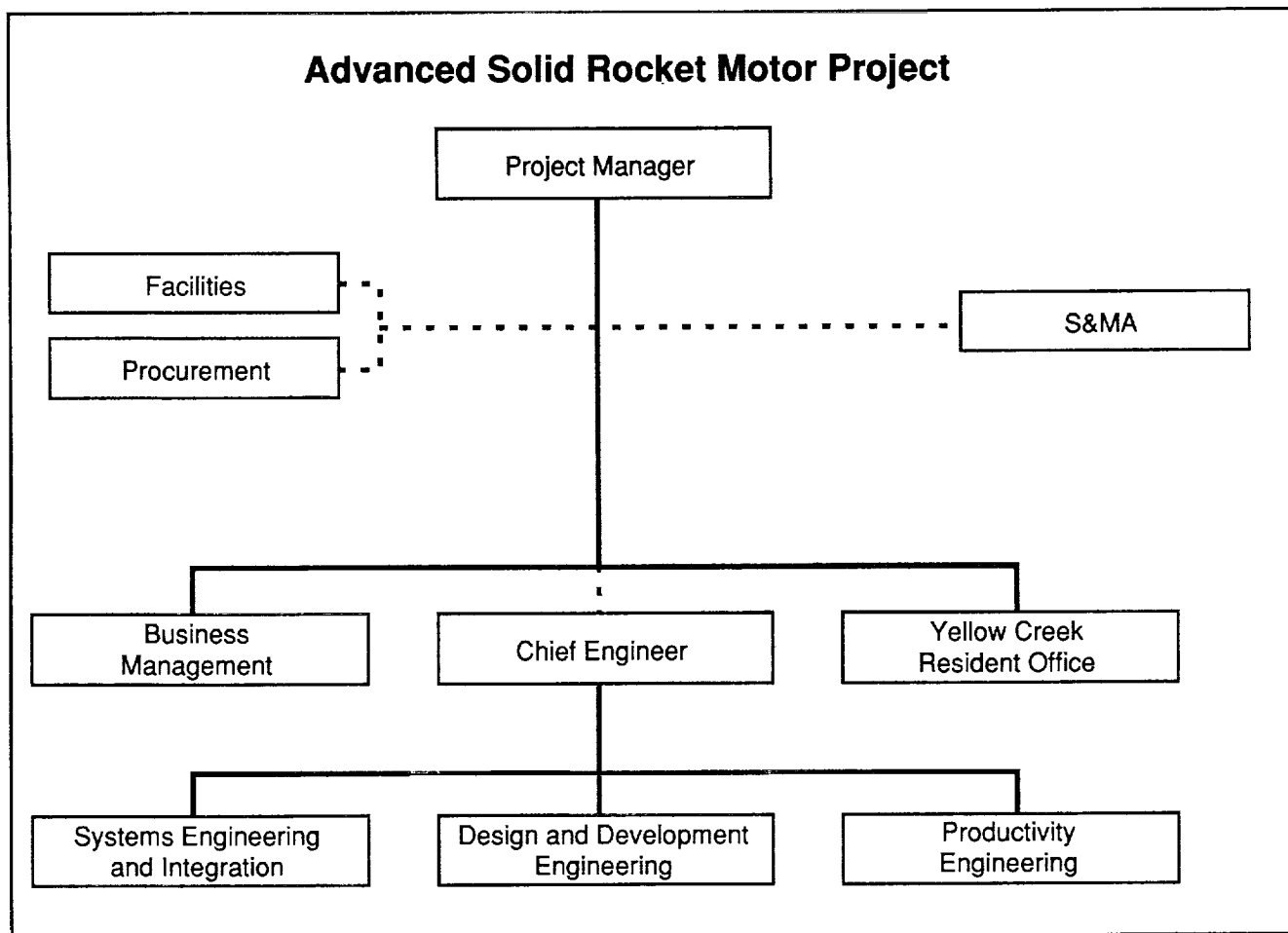


**Figure 8**

The Design and Development group and Productivity Engineering group interface with each other on a daily basis. This can be difficult because the two groups are matrixed to each other. This creates a division of labor, a feature typically found in a bureaucracy, where things sometimes go unattended or done twice. When the Chief Engineer's Office has a meeting with S&E concerning a product, usually one person from Design and Development supports it while up to three people from Productivity Engineering are needed. This uti-

lizes most of Productivity Engineering's resources while their actual productive time in the meeting is low. Having a matrix within the Chief Engineer's Office (Project Office) matrixed to the S&E Directorate, creates a "matrix within a matrix".

The management system for ASRM is the traditional MSFC chain of command. Until recently S&E personnel have not been allowed to sign inter-center memos. All external memos still must be signed by the Labora-



**Figure 9**

tory Director. Each laboratory has at least one lead engineer for each project. All information concerning that particular project is sent through the laboratory lead. This adds another layer of management control through which information or approval must be passed to reach the appropriate personnel. Following the chain of command process from the working level engineer in the laboratory to a working level engineer in the Chief Engineer's Office can go through as many as seven (7) layers of managers.

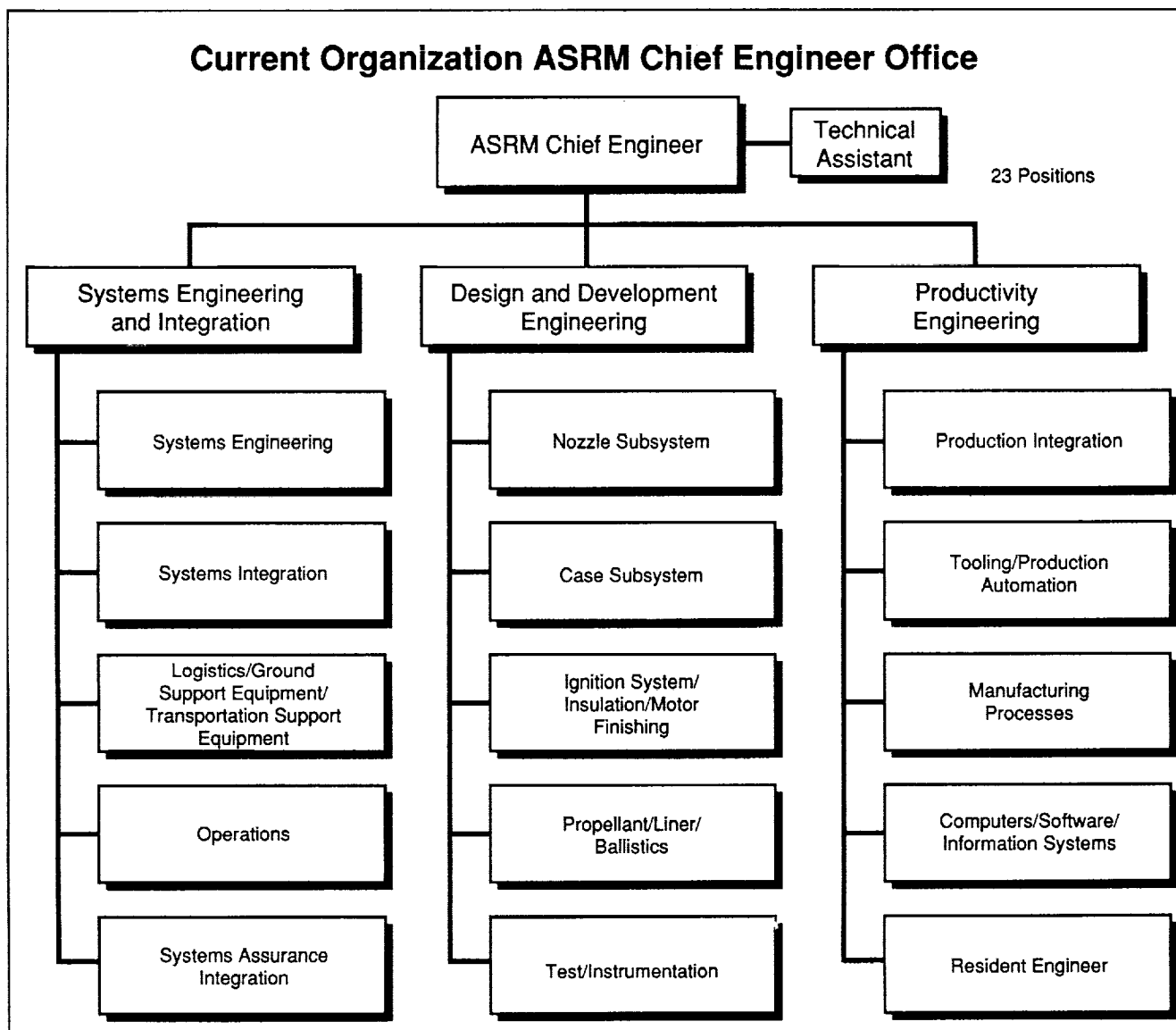
## Survey and Study Data Base

The MSFC Productivity Improvement Office and the Executive Steering Council recently administered a number of surveys to establish a clear understanding of existing culture, morale and employee perception of TQM status. These surveys serve as a "benchmark," a required activity when beginning TQM. The organization seeking change cannot know which direction to take or what to change without knowing which current positions, attitudes, and cultural barriers to change.

The first survey was the 1989 Culture Study and was intended to measure morale at MSFC. A consultant compiled the results and presented to MSFC management that morale was generally good and the results compared favorably with other NASA Centers. The survey avoided a comparison to industry in the area. The results were also compared to the 1986 morale survey, one that was taken in the timeframe soon after the *Challenger* accident and among employees who have since retired. The results of the survey, in presentation form, are shown in Appendix F.

The second survey was the TQM Benchmark Assessment. It was fashioned after the one used in the "Malcolm Baldrige Award" and was designed to solicit managers' estimates of the status of TQM implementation at MSFC. During one interview, it was observed that "managers with a higher degree of TQM awareness rated the MSFC progress lower and more objectively." The survey and results are shown in Appendix G.

Other ad hoc studies have been sponsored by the Executive Steering Council. One is the MSFC



**Figure 10**

Communication Study which involved a cross-functional team that compiled data through surveys and interviews. The results highlighted the fact that communication at MSFC is not completely effective. Contributors to poor communication, as presented to management by the study team were: chain of command, low use of electronic media, managers who are not people-oriented, and managers who use "not sharing information" as a method of retaining power. The results of this study are shown in Appendix H.

Another comprehensive ad hoc study was recently completed which addressed, in depth, the problems with the MSFC procurement system. This is a significant area to study, as it dramatically affects supportability to the project office. Findings included burdensome overregulation, centralized authority and

unnecessary signature cycles," as stated during interviews with members of the study team. The results of the study are shown in Appendix I.

A series of interviews was conducted by the authors that solicited TQM-related commentary from key personnel at MSFC who frequently interface with the ASRM Project. Those interviewed included MSFC top management, support organizations, a union official and ASRM management. Many of the statements offered by those interviewed are used as supporting references and illustrations herein. Those interviewed are listed in Appendix J.

Finally, a brief questionnaire was used within ASRM to determine motivational principles in use across the project's supporting functions. Based on the content of

individual responses, over 50 percent of the respondents to the "Motivational Principles in Use" survey were unfamiliar with 11 of the 16 more commonly used principles. Forty-five (45) percent of the respondents do not use any of the 16 principles and 64 percent of them use two or less. The questionnaire and a summary of the results are shown in Appendix K.

MSFC management is trying to develop a clear view of its culture, strengths, and weaknesses. Through the studies and surveys, the status of TQM is now becoming known. Results from the studies and surveys will be used in conjunction with defined TQM elements for the analysis and evaluation of TQM philosophies for ASRM. ■



# **A** nalysis and Evaluation

In analyzing the TQM Implementation Strategy for the ASRM project, "The Foundations of TQM" (fig. 3, page 8) and the "Westbrook Model for Engineering Management" (fig. 4, page 9) will serve as visual references. The definition of TQM as shown in figure 5 (page 9) and cultural elements shown in figure 6 (page 10) will serve as criteria throughout the analysis and evaluation.

## **Organizational-Wide Focus on Quality**

For years NASA prided itself on its "can do" attitude. During the Apollo days, scientists and engineers took pride in their products and felt responsible for them. However, as the Space Shuttle Program evolved, accountability traditionally assumed by the Civil Service employees and the accompanying work force shifted to the contractors who built the components.<sup>12</sup> Civil servants became contract monitors instead of actual "hands-on" experts. During the interviews many stated that, "Civil servants not maintaining hands-on expertise has eroded their knowledge of the products and processes."

One of the recommendations from the *Challenger* Accident Investigation Team was to form a "blanket" organization to be responsible for safety, reliability, maintainability, and quality assurance.<sup>13</sup> This organization, Safety and Mission Assurance (S&MA), reports directly to the NASA Administrator and is given full authority to stop any launch or any activity that does not adhere to specification, procedural requirements or accepted quality control practices.

Perception is reality until the perception is changed. This organization is perceived, however as trying to "inspect-in quality" rather than "ceasing dependence on inspection," as stated in Dr. W. Edwards Deming's third point.<sup>14</sup> In a recent Space Shuttle Projects Staff Meeting, for example, top NASA managers discussed budgeting for more inspectors and quality auditors, giving unknowing Senators and Congressmen the feeling that NASA is "buying more quality". This attitude is most visible when latent defects are found and S&MA is asked why they were not detected. Manufacturing should be asked why the defects were made in the first place.

As stated in one interview, "not everyone in the ASRM Project understands S&MA's role nor their own role in product quality." A clear understanding of S&MA's role is essential in implementing an organization-wide focus on quality.

## **Continuous Improvement**

In the context of TQM, "improvement" means the organized creation of beneficial change; the attainment of unprecedented levels of performance. Its synonym is "breakthrough".<sup>15</sup> There is much debate as to whether Japanese management techniques are superior to those practiced in America. Regardless of the debate, the Japanese viewpoint is that the Eastern and Western approaches to Kaizen (Continuous Improvement) are different. As listed in figure 7 (page 10), there are 12 features that the Japanese say distinguish the approaches. The Eastern management culture favors the Kaizen column, primarily supporting simple, conventional techniques. The Western culture favors sophisticated techniques and state-of-the-art technologies, expressed in terms of innovations.<sup>16</sup> The Japanese viewpoint fails to mention that it took 20 years to create the supportive culture, technology base, and infrastructure to only need continuous improvement.

In most respects the "innovation" column in figure 7 (page 10) accurately describes MSFC improvement approaches to date. The NASA culture is obsessed with technology, new inventions, and new theories. These are intermittent and non-incremental, resulting from individual ideas and efforts. Without "champions," the dramatic results obtained from the new technologies would never be realized. Although large investments are required, large paybacks result. According to members of the MSFC Productivity Office, the MSFC Productivity Enhancement Complex is designed to achieve this goal. The MSFC approach is used to eliminate specific problems in development and production of hardware, which is produced in low quantities and that undergo the rigors of space flight. The global debate for Kaizen versus innovation probably favors Kaizen, but for the survival of the aerospace business, innovations are essential.

Without deliberate change, the ASRM management culture will follow in the footsteps of MSFC and other projects. ASRM could easily come to rely only on technology innovations without realizing the added benefits of continuous improvement techniques. Breaking away from tradition and structuring a culture that uses the best features of both approaches offers obvious advantages. Over the next 20 years, commitment to more than the success of missions will be required. Teamwork, employee empowerment, reduced perception of rugged individualism, and collective efforts will generate a management style that is competitive globally. ASRM would have a style that distinguishes it from other projects like the "petunia in the onion patch".

## Extensive Use of Measurements

MSFC is predominantly a technical organization, completely comfortable with numbers relating to vehicle design, performance, statistics, cost, and schedule. When it comes to measurement of productivity of that same organization, it is pushed outside its comfort zone. MSFC (including ASRM) management tends to be more results-oriented than process-oriented in their measurements.

Results-oriented management is defined as the style of management that is well established in the U.S. which deals at the bottom line. It emphasizes controls, performance, results and rewards (or the denial of rewards and even penalties). These criteria are easily quantifiable and short term.<sup>17</sup>

Process-oriented management is the style of management that is people-oriented and that deals with how results are obtained, much in contrast to styles oriented solely toward results. In process-oriented management employees are provided a supportive cultural environment in which to do their jobs. Such a style of management calls for a long-term outlook and usually requires a behavioral change. Some criteria for meriting rewards in this style are discipline, time, management, skill development, participation and involvement, morale, and communication.<sup>18</sup>

During interviews, it was stated that "MSFC cultivates predominantly bottom-line managers." They use mechanistic controls (award fee, performance evaluations) and numerical goals (dollars, schedules, production quotas) to control and evaluate their projects. The MSFC Culture Study (Appendix F) supports this where respondents believe that accomplishing goals is

the best way effectiveness is measured. Contracts for these programs, including ASRM, are written to accommodate this type of management philosophy. This is partially due to the environment created by Congress in federally funded programs.

If ASRM managers are to depart from their dominant MSFC culture and become more process-oriented, the focus must be on how goals are accomplished, people, processes, and quality. Management must clearly define goals and then provide support to the people who accomplish them. If non-value added impediments exist in accomplishing goals, it is management's job to remove them. Many of those interviewed stated the "people should be regarded as valuable assets that will depreciate if continuous training is not received and if proper care is not taken with respect to their achievement needs." When an employee has been allowed to become fully motivated and trained, the employee's potential can only be released with empowerment to do the work assignment. The results often surpass the expectations of management. A manager should never underestimate the potential of the organization's most valuable resource—people.

In accordance with figure 3 (page 8), people using tools and methods result in Statistical Process Control (SPC). First the people involved must be qualified through education and continued training. They should be current with technology and be able to apply the correct tools to the work situation, such as the graphs, plots, and control charts shown in Appendices E and M. Then management must freely provide these tools, methods, techniques, and technologies and fully expect their use. TQM is not only control elements like methods and tools but also people using them to solve problems.

The lack of process control in manufacturing is one of the most prevalent problems in the U.S. today.<sup>19</sup> Projects like ASRM are no different. Project Office personnel rarely take the time to fully understand the processes used for manufacturing a product such as the ASRM, yet management continually expresses interest in higher productivity. One of the first lessons learned in implementing TQM is that productivity is not possible without first establishing quality. There is nothing productive about scrap and rework. The lesson continues with the reality that quality does not exist until the process is under control, reducing variability for product uniformity.

SPC is becoming more than just a buzzword. As people begin to understand SPC, they must understand which variables require control and to what degree. To



determine these, some type of experimental design (i.e., Fraction Factorial, Taguchi) is best used in order to optimize the processes and products.

Some well-established projects within the Shuttle Projects Office that are considered to have successful products (relative to cost, schedule, and performance) measure quality trends at a very high level. Appendix L is an example of information contained in the monthly performance trends report for one such project. Very high-level reporting methods are typical across most MSFC projects. Discrepancies are measured in terms of 1,000 hours worked—a relationship unsupported by modern SPC techniques. Also, the number of latent defects reported clearly shows that 100 percent inspection does not produce 100 percent quality. With SPC on the horizon, reporting methods will necessarily change to reflect product variability as opposed to unrelated factors.

One more example of the ASRM project being a “lonely petunia in the onion patch” will be work station level process control at the manufacturing site. The ASRM project is structured to use a high degree of automation and real-time process control. Operators well trained in control techniques will occupy each work station and clearly display the control charts for the process. This would represent a departure from the current practice of high-level “looks” that depend on low-level “tight tolerances” to keep the product within specification. ASRM quality trends will appropriately represent an upward flow of work station information. Other projects will probably continue to “measure with a micrometer and cut with an ax”. Other projects will probably continue to claim real progress in SPC; a claim without foundation until process control charts are routinely displayed at each work station.

The ASRM contractors will use a five-phase process control program: development, characterization, verification, control, and improvement. This program provides the employees with the tools to reach their goals and continuously improve. Statistical tools such as cause-and-effect (Ishikawa) diagrams, control charts (X-bar and R), quality spread sheets, histograms, Pareto diagrams, scatterplots, flowcharts, and graphs represent many of the tools available for the employee to understand and control their processes.<sup>20</sup> It will be imperative that ASRM Chief Engineer personnel, support S&E personnel and S&MA representatives understand and be able to utilize the tools being employed by their ASRM contractor counterparts. Appendix M contains examples of specific techniques

for design requirements, such as Quality Function Deployment (QFD), and the process control program planned by the ASRM contractors.

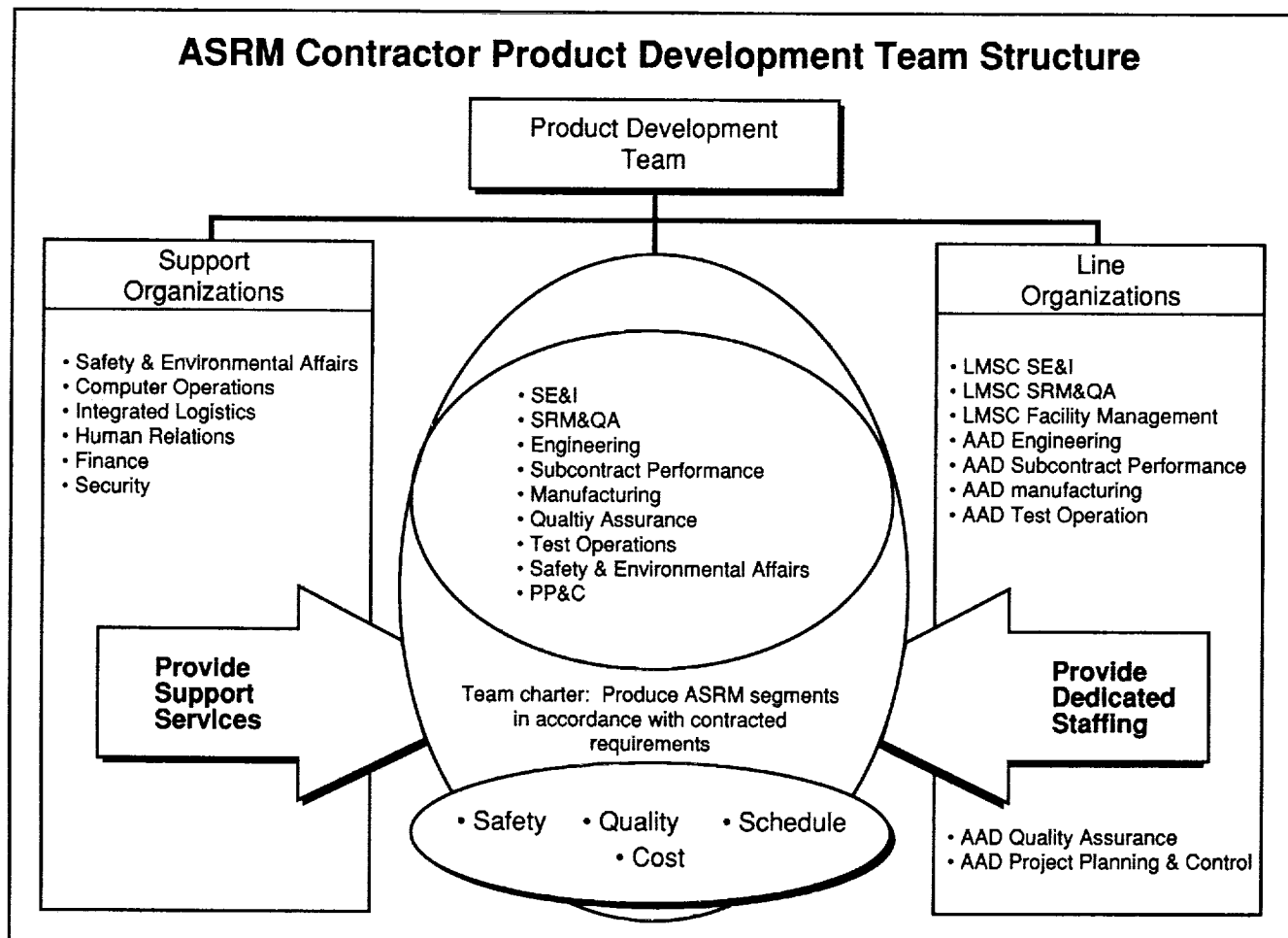
NASA has promoted quality for years, especially since the *Challenger* accident. ASRM will express quality in terms of “tight product uniformity around a target” and not as “conformance to specs”. With training based on methods from Deming, Juran, Taguchi, and others, employees will understand why controlling the process is important to the design and performance of their product.

## Cross-Functional Teams Solving Organizational Problems

Teams at MSFC are primarily functional teams like NASA Employee Teams (NET's) which are chartered to solve problems in their specific organization. Private industry knows these teams as Quality Circles. The word “team” is often used to describe an organization like the “Shuttle Projects Team”. The only true, cross-functional teams are those ad hoc teams or “Tiger Teams” which are formed to solve a specific problem when the existing organization cannot react in an acceptable timeframe. These ad hoc organizations have an unbelievable track record of success. Participation on such a team is usually one of the more memorable experiences in one's career because an “ad hococracy” is relieved of organizational boundaries, certain policies, and are rewarded for successful completion.

In order to examine teamwork in the ASRM Project, both the contractor and NASA organizations must be examined. The contractors (Lockheed, Aerojet, Thiokol, Babcock & Wilcox and Rust) utilize cross-functional teams called Product Development Teams (PDT). They are completely responsible for the design and manufacture of their specific product and the product's facility design and activation (fig. 11, page 20). The PDT's are designed to satisfy both internal and external customers. These teams meet on a weekly basis with an open invitation to NASA personnel to attend as observers. Contractual requirements do not allow NASA personnel to be members of a PDT.

During interviews, concern was expressed over the way the PDT's operate and the way NASA interfaces with the PDT's. This can be attributed to three reasons: (1) PDT's have only been established for just over a year in which the majority of the PDT personnel have been transferred to Iuka, Mississippi, (2) ASRM



**Figure 11**

personnel have not organized or been trained to effectively use teamwork, and (3) team outputs are hard to control. All will improve with time, training, exposure, and experience.

As previously mentioned, the ASRM Project does not routinely utilize cross-functional teamwork. This is primarily due to the fact that teams are not viewed as a viable means of management. ASRM (and MSFC) must use teamwork to maximize the utilization of its people. The use of teams would be particularly helpful in the ASRM Project to complement the contractor's PDT's whose members interface with NASA personnel on a daily or weekly basis.

## Customer Focus

Increased sensitivity to and focus on customer needs is one of the most important and pressing requirements for a Total Quality Company. Without this constancy of purpose, no company is likely to succeed in a competitive environment.

According to Juran, a customer is anyone who receives or is affected by the product or process. Customers may be external or internal.

"External customers" are affected by the product but are not members of the company that produces the product. External customers include clients who buy the product, government regulatory bodies and the public (which may be affected by unsafe products or damage to the environment).

"Internal customers" are affected by the product and are also members of the company that produces the product. They are often called customers despite the fact that they are not customers in the dictionary sense; that is, they are not clients. However, they receive an output from a person, group, or internal organization.<sup>21</sup>

In further discussions, Juran says that product satisfaction is a result achieved when product features respond to customer needs. It is generally synonymous with customer satisfaction. Product satisfaction is a stimulus to product stability. That is why clients buy the product.

A product deficiency is a product failure that results in product dissatisfaction. Product deficiencies take such forms as power outages, failure to meet delivery dates, inoperable goods, blemished appearance, and non-conformance to specification. The major impact is on the costs incurred to redo prior work and to respond to customer complaints.

During the interviews, many support organization directors stated that they were encouraging their managers to identify their customers and have meetings with them to solve any problems that exist. The Comptroller's Office, for example, is responsible for financial activity and considers virtually all MSFC functions as customers. Rather than being overwhelmed with the scope of hundreds of interfaces, managers began meeting with internal customers to eliminate differences. Reports from their customers indicate a higher degree of satisfaction with the financial organization's service over the past year. Although policies, procedures, and other constraints imposed by MSFC external customers (from NASA Headquarters and the OMB) may be difficult to avoid, the internal customers to the financial organization feel more comfortable with the ability to influence their destiny.

There are occasions when ASRM Project support organizations have internal customer conflicts which affect the ultimate customer. During one interview, it was stated "there are two organizations with a major processing problem that desperately needs resolution". Procurement and the Engineering Management (EM) Division of S&E have a complex relationship. EM is the business management function of S&E that allocates funding and processes purchase requirements, representing a sizeable portion of the MSFC in-house activity. Procurement is the contract representative and is the only lawfully authorized organization to buy for the government.

The bureaucratic organizational form at MSFC has created a tangled relationship. Over the years, the management of EM has allowed "signature creep". It now can take as many as fourteen (14) signatures to approve a purchase request of relatively low dollar value. This process in itself can take weeks or months to work through the system, as illustrated in Appendix I. The relationship between EM and Procurement becomes tangled when Procurement is required as part of EM's iterative approval process. The two organizations are placed in the position of taking turns being each other's customer. Those organizations have not been trained in TQM and customer awareness tech-

niques. It is confusing and frustrating to those involved and the results are counterproductive.

If the EM and Procurement scenario was presented as a manufacturing problem where a product repeatedly cycled between operations in a manufacturing cell, the lost time would not be permitted. It would be too costly. An analysis would be conducted to optimize flow, set-up, lead times, and interfaces. The EM and Procurement scenario is analogous. Fourteen signatures on a routine purchase wastes valuable human resources and frustrates the groups involved. The entire system begs to be simplified and optimized.

The external customer arrangement for the ASRM Project is complex in that it is multilayered. ASRM is designated as Level III in the agency hierarchy and is directly influenced by Level II, which is at Johnson Space Center (JSC) in Houston, Texas. This hierarchy includes technical systems integration and budget. Both Level III and Level II receive direction from Level I at NASA Headquarters in Washington, D.C. Headquarters in turn receives direction from any number of sources, including the President of the United States, the Vice-President, Congress, Senate, and an untold number of special committees.

The ASRM Project is also bound by the policies levied by other agencies such as the Office of Personnel Management (OPM), the OMB, and even the DoD who dominates the basic standards and specifications by which the ASRM is built. The entanglement increases since these policies, standards, specifications and other requirements are enforced through the organizations that support the ASRM Project, like the Comptroller's Office, Personnel and S&E. It gives them the appearance, but not the legitimate authority, of being a customer to ASRM. Some personnel interviewed remarked that this made various support organizations act like customers, causing resentment among those who dealt with them. In reality, the support organizations act as agents to translate policies from governing bodies, and for a brief period become the customer.

A good example is Personnel, who must regard every organization as an internal customer. Regulations on promotions are passed on by the OPM. Personnel insures that promotions for customers like the ASRM Project are executed in a timely manner but in accordance with federal law. During the iterative activities associated with the selection of a promotion candidate, the project representatives must prepare and submit documents and forms suitable to the process. Person-

nel is the internal customer or recipient of this package from the prior process and relies on the ASRM Project to provide a quality product requiring no rework. Although it is difficult sometimes to view support organizations as customers, they are customers when the process is iterative.

As long as governing agencies outside NASA's control enforce regulations through support organizations, all organizations will be customers at times and will respond to customer needs at other times. It will be important to be able to distinguish which is which, at what time, and behave accordingly.

Customer recognition and sensitivity to needs should be one of the first areas of focus in TQM training and one of the first targets for behavioral modification. As Juran described it, customer awareness would represent a dramatic culture change for the ASRM Project and its MSFC support organizations, one that would offer unimaginable benefits.

## Culture

The ASRM cultural analysis criteria is contained in figure 6 (page 10). Since the ASRM Project recently began, its culture is still dominated by the MSFC belief system and infrastructure. Therein exists the opportunity to adopt only those cultural aspects that favor TQM. To effectively change the operating mode and management philosophy of any organization, a clear understanding of the culture is necessary. In accordance with information obtained through the referenced surveys, studies, and interviews with key personnel, the MSFC culture is explained in the context of figure 6. Those aspects of the MSFC culture that are expected to impact TQM in the ASRM Project will be emphasized.

## Language

Every culture has a language and its characteristics help define the existing culture. Since outsiders such as customers, vendors, and those not in the immediate business unit usually find difficulty learning the language, it serves to attack the intruder.

Of the five primary elements that compose a language, the *jargon* used in the culture that surrounds ASRM is the most influential in maintaining the status quo. The use of acronyms and abbreviations is a natural part of any conversation or presentation. In fact, their use is so popular that an official NASA publication lists some 16,000 approved acronyms. Of course, this represents

only a portion of those used and many emerging subcultures, such as the ASRM Project, have local jargon which serves as a communication barrier to even its closest neighbors. Jargon is sometimes used to keep outsiders out, inhibiting team building, problem solving, and communication with customers. It also holds "change masters" at bay.

A *metaphor* is the application of a phrase to an object it does not denote, and is often used in a negative sense. TQM principles require a high regard for the customer. The Air Force, for example, is frequently a customer but certainly overhears the reference "blue suits". This phrase does not promote a positive relationship with the customer.

*Myths, stories and heroes* also serve as part of a language, reliving events that only those within the culture can appreciate and idolizing personalities a newcomer will never know. The favorite story at Federal Express involves the founder Fred Smith gambling in Las Vegas to save the company's payroll. At Arnold Engineering Development Center (AEDC) near Tullahoma, Tennessee one could hear the accounts of Von Karman starting up the Center wind tunnels by playing with the switches. For charter members of MSFC, the adventures of Wernher von Braun and the Germans go well with coffee. For new employees the stories entertain them only once. For outsiders, the coffee alone is sufficient.

ASRM must change the language to change the culture. If managers use negative expressions about customers, it reflects poorly on TQM. Although acronyms are a way of life for ASRM, a positive approach to communications will be necessary in a TQM environment.

## Ceremonies and Celebrations

Ceremonies and celebrations serve to keep tradition alive by lending significance to doing things "the way we did it last year". In most respects, celebration is good. AMWAY, for example, survives on its parties to keep the work force excited. Mary Kay Cosmetics and IBM celebrate the achievement of sales goals. Mary Kay goes so far as to reward achievement with fur coats and pink Cadillacs.

MSFC celebrates certain holidays and anniversaries, thereby promoting family unity. Also celebrated are certain achievements. The first astronauts to reach space and orbit the Earth were milestones well celebrated. The Apollo Program which resulted in man walking on the Moon was well celebrated. The

successful launch of the first space shuttle was good reason for celebration as it not only signified a technical achievement but marked the beginning of routine travel to space. It is interesting to observe that although each space shuttle launch requires the same technical achievement as the first, launches have become routine enough to no longer warrant celebration. In fact as the solid rocket boosters are spent and jettisoned two minutes into launch, many SRB personnel leave the viewing room. "Their job is over" and the other 6.5 minutes of ascent are for others to worry. It is possible that when celebration of the team's achievement stopped, so did part of the team's unity. A valuable lesson learned for the ASRM Project is to consider the celebration of every successful launch and supporting other projects on the launch team until orbit is achieved.

### **Artifacts and Symbols**

Artifacts and symbols send a silent and clear message about the welcomeness of a newcomer or a new philosophy. Government practices are similar to many traditional private businesses where executive offices are lavish, the organization chart is emphasized, and parking slots are restricted. The ASRM Project will follow the MSFC culture. Office size will be determined by position and measured by number of windows. The organization chart may be simple but will be structured like all others. One recent attempt to humanize some organization charts by replacing the blocks with color photographs of the managers is a commendable improvement and offers a "welcome" to newcomers. The organization charts that use pictures of varying sizes to denote rank may not offer the welcome intended.

The culture introduced by the Japanese is less concerned with bureaucratic symbols. The companies intensely competing with the Japanese are also eliminating many outdated inhibitors. The Saturn Corporation in Spring Hill, Tennessee for example, considers a neck tie unnecessary. The main drive to the plant was named after the union official who was instrumental in pioneering new management-labor concepts employed at Saturn. These are symbols that send a message of welcome.

### **Patterns of Behavior**

There are several reinforcements to the way one acts that will counter change. *Rites and rituals* are informally observed when things are done the same way time after time without question. One cultural reality is the "etched in stone" regard for NMI's and MMI's

(Marshall Management Instructions). These instructions serve as external influences on the ASRM Project. It is typical of bureaucratic organizations that these instructions be put in place by top management for tight control of operations, many times to the detriment of cost and performance of a project.

Another cultural reality is that NASA is a part of the Civil Service System. There are literally thousands of rules and regulations by which to abide, many relating to performance evaluation. During the interviews, many perceived that promotions and certain types of pay increases had little to do with actual performance. Leaders in the philosophies and founding principles of TQM tend to agree with this perception. Deming recommends abolishing the performance appraisal system, citing that it destroys initiative and breeds mediocrity. The performance evaluation process leads the list of complaints and grievances filed against management at MSFC. Unfair performance appraisals are the result of a bureaucratic procedure used for reporting, inadequate training for supervisors, or both. The performance appraisal process at MSFC is cumbersome and lengthy, requiring a lot of the supervisor's time. Embellishment is usually required for high ratings. Supervisors seldom feel responsibility for an employee's low rating, regarding the rating as the employee's fault. It was expressed during one interview that the OPM would never approve a performance appraisal format that could be done on one page, front and back. An opposing opinion was stated in another interview that "to be able to do this would be an improvement as it is hard to get very much bureaucracy on one sheet of paper".

It is MSFC policy to recruit new hires with a grade point average of 3.5 or higher whenever possible. If these outstanding students have been motivated for the past 17 years to maintain excellent performance in academics, one would expect their bias toward achievement to continue and their ratings as employees to be "outstanding". If the rating is less, the rating system or the supervisor should be suspect.

Externally motivated rituals are commonplace as they are passed on to the ASRM Project by the dominant culture. A good example is the required signing of time cards for employees who usually charge 40 hours per week and do not get paid for overtime. Another is signing travel vouchers that seldom require close scrutiny. An interesting example is the signing of leave slips (vacation authorization). The official purpose is to inform management that an employee desires time off on certain days and receive approval for that leave.

The leave slips are actually used later by the employee as evidence of approval. Although there are no recent accounts of managers retracting approval irresponsibly, it is suspected that the system is living with sins of the past. Policy was changed over a year ago to require leave slips only for blocks of three days or longer. Newer employees responded readily to the improved conditions while long-standing employees still submitted leave slips for all occasions. Such rituals send a message of mutual mistrust between workers and management. One way to begin the ASRM culture on a positive note is to seek out and eliminate rituals such as these that are counter to trusting the employee.

A familiar phrase in the culture that surrounds the ASRM Project is "shoot the messenger". This refers to the certain demise of the bearer of bad news or someone who locates a problem and brings it to management's attention. In Japanese industry, such a person is an asset to the problem-solving effort. This area improved after the *Challenger* accident. One person interviewed stated that "ignoring the messenger" is still widely practiced. "Rewarding the messenger" would be one measurement of the effectiveness of a culture shift.

*Behavioral norms* relate to what is perceived to be accepted behavior. Following the chain of command is definitely a government-wide expectation, practiced to the extent that some even wait for permission to do the obvious. There are also standards of behavior and speech that are closely followed. For example, upon reaching certain levels of manager and executive, the culture assigns the label of "Mr.," "Ms.," or "Dr." These labels are used to introduce management to outsiders as well as employees. It is perceived that it would be outside the acceptable tolerance band of behavior and speech to use first names, since a manager's closest employee, the secretary, is usually the one who leads the introduction with the label and uses it during conversation. These labels can become a convenient way for all involved to maintain barriers to open communication, never having to know someone well enough for a trusting relationship to develop.

It is being considered that during the next scheduled rebadging for MSFC personnel, the employee's first name will be added to the face of the badge. Many NASA contractors have already taken this step. This would represent a positive cultural change and send a message of openness and welcome. If accepted behavior still requires the same labels, the message could be ambiguous and confusing.

*Beliefs and values* are justification of norms. One belief expressed during an interview was that "unless

you are in S&E, you have no technical competence". This perception is supported time after time as S&E engineers move to the project offices and are no longer regarded as engineers. A statement made during another interview was that "some non-technical team members perceive that they are not regarded as first class professionals when attending a meeting with engineers and scientists." Beliefs and values, even of this magnitude, can and should be changed through training and communication.

*Subcultures* are small or large groups of people which represent "for or against" organizations. One subculture at MSFC overtook the dominant culture in 1983 when the Data General computer system was implemented. The subculture for modernization included a strong leader and a secretarial work force that was tired of the status quo. Many resisted vigorously but the silent majority of the workforce wanted computers, word processing, and electronic mail. The silent majority won.

It should be noted that most places, whether private industry or government, where TQM is being applied has a culture that probably rejects it. Although TQM is not difficult to apply, it will probably fail for many who attempt it due to the management and worker mindset "We don't do things that way here". The challenge is for the TQM subculture, much like the one developing in the ASRM Project, to emerge dominant. The other challenge is for ASRM to be treated as a Total Quality Company and not as a government project.

## Education and Training

Training at MSFC is primarily tuned to skill retention for daily operations. TQM and the task of advancing technology are accommodated differently. Seminars such as those offered by the Deming Institute are attended off-site by selected employees. Focus seminars (Taguchi Methods, etc.) are offered on-site by organizations such as the American Supplier Institute (ASI). Universities supplement the TQM curriculum through courses in Engineering Management offered by Tennessee, Auburn, and Alabama which closely correlate to TQM's founding principles.

According to Philip B. Crosby, the overall educational aspect of Quality Management requires an executive, management, and employee education system so everyone can comprehend their roles. The purpose of executive education is to help senior people understand their role in causing problems and then causing improvement in the quality process. Because they are

the overall managers of the company, everything they do is important and watched. In management education all the content from the executive education should be covered with the addition of several items in great detail to enable them to make the necessary communication to the employees. The other 95 percent of the people in the company should get videos, workshops, and materials that can be taken back to the workplace and applied as it relates to real life.<sup>22</sup>

MSFC has initiated training in TQM on-site beginning with selected managers. This is a prelude to a center-wide program. Managers will receive two days of instruction while the work force will eventually receive a two-hour awareness session. The training budget for this effort totals \$400,000 during 1991, with university curriculum and special courses in addition to that. The on-site sessions will be conducted by ASI, a firm who has offered TQM courses previously at MSFC in design parameter and process control. The current ASI course material is general, incorporating teamwork and other aspects of TQM. The balancing effect of the behavioral sciences, including Herzberg's Theory of Job Satisfaction, Maslow's Hierarchy of Human Needs, and McGregor's Theory X and Theory Y, are offered in some MSFC middle and upper management courses (Appendix N). Without the balance of motivated people, the tools and methods offered by Taguchi cannot be effective.

Education is essential to TQM. It will become obvious in a short time that employee empowerment is the force that frees the "entrepreneurs". According to Rosabeth Moss Kanter, "corporate entrepreneurs" are often the authors not of the grand gesture but of the quiet innovation. They are the ones who translate the strategy—set at the top—into actual practice, and by doing so, shape what the strategy turns out to mean.<sup>23</sup> The TQM training at MSFC should be structured for the emergence of the entrepreneur.

The \$400,000 TQM training budget for 1991, MSFC sponsorship of Engineering Management curriculums, and special short courses, seminars, and colloquiums certainly indicate a "top management commitment" to TQM education. Analysis of the existing culture, however indicates that a number of barriers to change exist and that the culture change necessary for TQM will be difficult. There is risk in training an entire work force in the principles of TQM. From that point on, they know management's role. If management is not willing to play out the new role, the workforce will know the difference and the newest fad will no longer be in vogue.

The Xerox Corporation and other American companies faced with extinction adopted "Cascade Training" as the ultimate demonstration of management commitment.<sup>24</sup> "You don't learn it until you teach it" became the motto at Xerox. Executive management was trained and, in turn, trained the next level of management. Training cascaded through the levels of management in this manner until the message reached the workforce. Lack of sincerity was as easily detected as strong commitment. "Cascade Training" would be the ultimate test and its success would convince the project's work force and supporters that ASRM managers know what they are talking about and believe what they say.

## **ASRM Influence on Other Organizations**

The ASRM Project is committed to a different beginning. Other projects and organizations talk about TQM and some use a few Taguchi methods. ASRM has the opportunity to serve as the example—to be the "lonely little petunia in the onion patch".

The brightly colored petunia will have an increasing impact on existing projects, especially its peers in the immediate Shuttle organization. The previous frontrunner projects will have a new competitor who sponsors a comprehensive program of continuous improvement. A high regard for people could set up a migration of talent from projects who manage by Theory X control rather than through leadership. It will prove that Theory X and hygienics do not work very well in an educated, success-oriented workforce and that Theory Y and satisfiers are more effective. In short, it will change the management style in the neighboring organizations because the workforce will require it.

Future projects should not be managed like the existing ones. New tools and philosophies should prevail and the example set by ASRM should be a guiding light. The ASRM model will change the complexion of manufacturing for future projects, giving rise to SPC and real-time process control charts posted at every work station. The ASRM may serve as a workforce seedbed, training employees for future projects in the ways of TQM. Transferring these employees as the Statement of Work is being developed for a new project would guarantee a change in the structuring of future Requests for Proposal. New ways to measure contractor performance could result in being oriented toward product uniformity and cross-functional team effectiveness.

Finally, support organizations that view the ASRM Project as a customer will adopt a new relationship built on the realization that "nobody is a customer all the time". Visibility of a positive relationship with ASRM will affect all support groups who would certainly want to be treated the same way. The story continues with the realization among support groups that, if knowing how to be a customer and then a

supporter works with ASRM, it can certainly work *between* support organizations.

Having the strength of character to be a petunia is hard, but the success from it has been proven over and over. A positive model is contagious, especially when others are tired of being an onion and find that they also can be a petunia. ■



# **R**ecommendations

In accordance with an Effect-Cause-Effect analysis, 20 percent of the potential remedies will have 80 percent of the success. This 20 percent is called the core. Problems in the core have underlying causes and a wide impact. Remedies applied to the core change the system versus finding a change within the system. These remedies change persistent habits.

The analysis previously presented was based on a literature search, interviews, surveys, studies, and material received from Engineering Management courses and topic related seminars. The analysis has resulted in a number of recommendations regarding the implementation of TQM. These recommendations are summarized below with expanding comments following. They are classified as specific recommendations for the ASRM Project and systematic changes for MSFC.

## **Specific ASRM Recommendations**

1. Develop a clearly stated direction for TQM Implementation in the ASRM Project based on accepted definitions.
2. Assure visible commitment of management to TQM.
3. Demonstrate employee trust by empowering a highly competent work force to make decisions and do the work.
4. Initiate "Cascade Training."
5. Prioritize training for ASRM project and support personnel and use as Total Quality Company pilot project.
6. Specially train and develop S&MA representatives in the ASRM Project as SPC "coaches"; eliminate the "inspector" image.
7. Pilot core cultural improvements with cross-functional teams.
8. Reorganize ASRM Chief Engineer's Office to support cross-functional, product-oriented teams as a TQM pilot.

## **TQM Recommendations —ASRM Project**

1. Develop a clear vision statement that tells employees where ASRM project management expects to lead them in TQM during the next two years and set goals for the next ten years using accepted definitions. Provide the "how-to" guidelines, associating the processes closely to the training being offered. Avoid interpreting TQM to fit easily and routinely into the management style of the dominant culture. Develop the management style to fit TQM.
2. Make a visible commitment to TQM, top to bottom organizationally, ensuring that every employee is convinced of the commitment. Conduct monthly TQM seminars, colloquiums, and include as a topic in telecons and reviews.
3. Empower employees by pushing decision-making to the lowest levels possible. Eliminate centralized decision-making, hoarding of information, and communication filters. As employees are accustomed to the dominant culture, they must be informed of the empowerment. Teams cannot be effective without the power to effect an outcome.
4. Initiate a "Cascade Training" policy for managers. Cascade training assures "TQM knowledgeable" management, reinforces commitment, and strengthens the future cultural norm.
5. Prioritize TQM training for ASRM managers and internal support group managers and use ASRM as the test case for treating a government project like a Total Quality Company. The ASRM Project should be a success model to serve as a "petunia in the onion patch".
6. Develop the ASRM Project S&MA representatives as SPC coaches. Eliminate the image of "procedure police" and "inspectors". Enable S&MA to become an organization that provides leadership in real-time process control, properly applied and visibly displayed control charts, and minimizing inspection. Enable S&MA to lead the culture shift from "meeting spec" to "uniformity around the target value". Enable S&MA to pilot the change from management reports that measure

defects based on unrelated data to a reporting system that feeds meaningful information up from the workstation or activity.

7. Develop the ASRM culture to intentionally address TQM principles, tools, and philosophies. Challenge the bureaucracy on counterproductive norms and depart from them. Conduct cross-functional teams to pilot:
  - (a) **The one sheet performance appraisal.** The format concept is to be determined. The goal is to separate performance that can only be "met" from that representing extraordinary achievement or effort. The narrative should be limited to one-third page and all supervisors trained in the new system's use.
  - (b) **New communication paths between internal customers.** Simply becoming a team and meeting establishes informal links. Experiment with team directed listings in electronic mail. Evaluate the impacts of eliminating unnecessary "chain of command" and test the new employee empowerment with lower level decision making.
  - (c) **Scheduling and SPC techniques that track variability and effectiveness of the government activities, using applicable software.**

First pilots could be technical evaluations, pricing, legal opinions, personnel actions, and other support elements that are measurable.

8. In analyzing the current ASRM organization (fig. 9, page 13) for the forming of teams, representatives from the following organizations would be a requirement for each team: Chief Engineer (2-4 people), Business Management (one person), facilities (one person), procurement (one person), S&MA (one person), and the S&E Laboratories (between 5-25 people). Representatives from staff offices (Comptroller, Chief Council) should be added when appropriate (fig. 12). Their organization should be an "All-Channel Network" with open lines of communication between each element and decentralized decision making.<sup>25</sup> These teams should be product oriented (like the PDT's) and should be responsible for all MSFC activities related to that product. Recommended teams are: Nozzle, Case, Ignition Systems/Motor Finishing, Propellant/Loaded Segment, Insulated/Lined Segment, and Motor Test. It is also recommended that a Computer/Information Systems team be formed and facilitated by project office personnel instead of Chief Engineer personnel. These teams should be pro-active instead of reactive as the MSFC Communication Study Team Report (Appendix H) states.

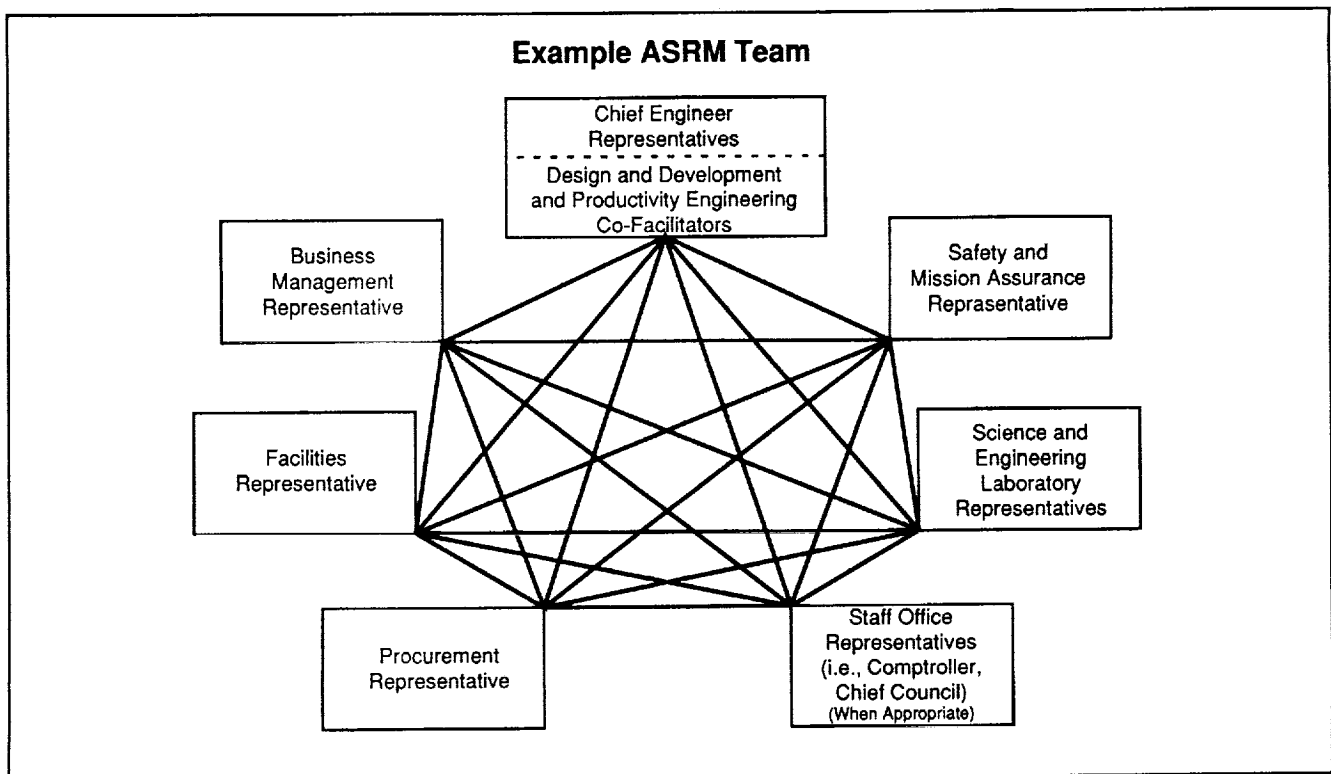


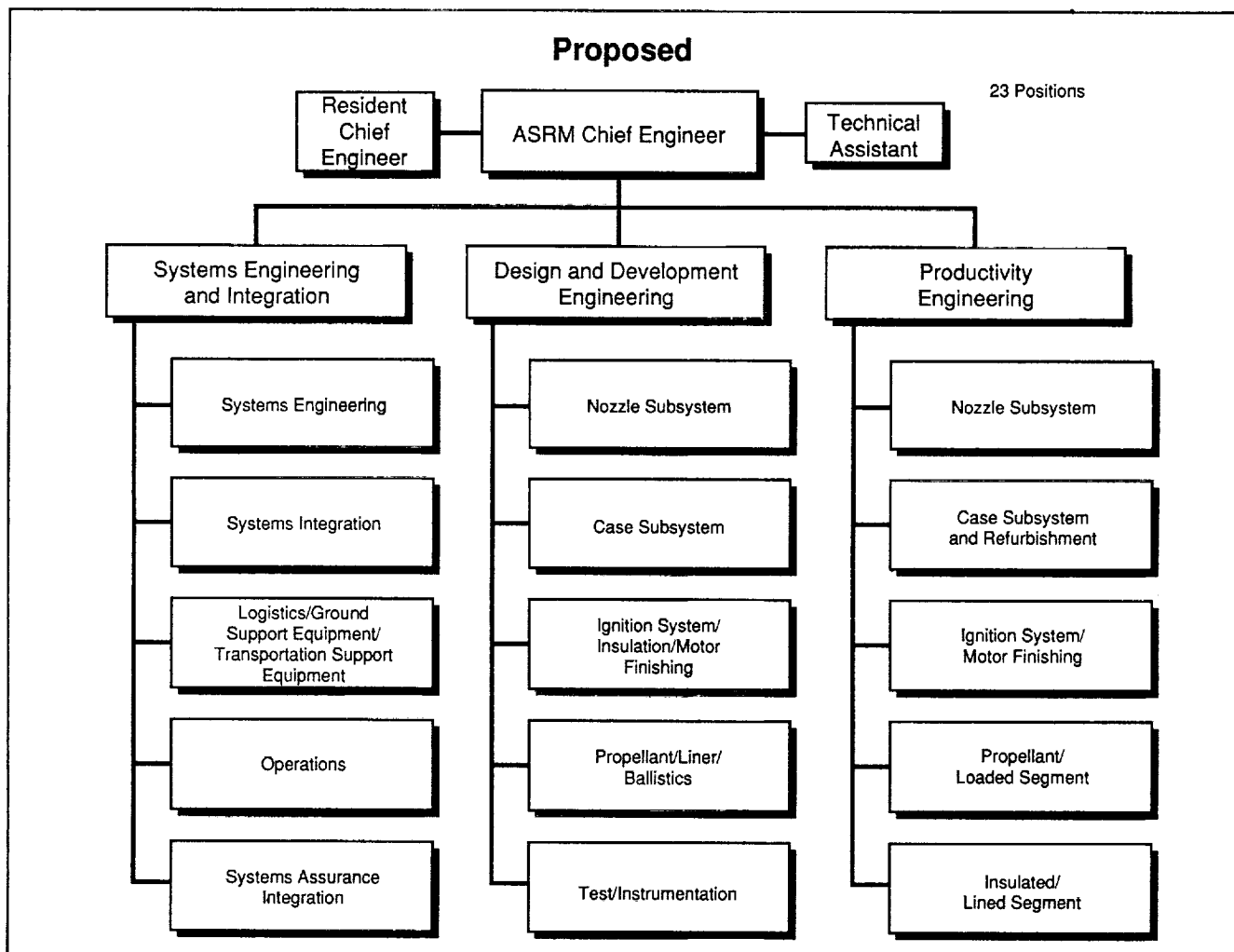
Figure 12

The organizational representatives could readily support teams (with proper training) without formal reorganization with the exception of the Productivity Engineering group in the Chief Engineer's Office. The Productivity Engineering group would be more effective if it was product oriented like the Design and Development group. They should be reorganized in the following manner:

1. Have the Chief Engineer's representative who is resident at Iuka, Mississippi report to the Chief Engineer instead of to the Productivity Engineering Manager (fig. 13). It is perceived that this individual is the Productivity Engineering representative—not the Chief Engineer's.
2. Reassign the computer/software/information systems person as a direct report to the Project Manager (fig. 14, page 30). This effort is the backbone of the ASRM Project (automation) and requires project resources and across the board visibility, not just S&E.

3. The remaining three positions (Production Integration, Tooling/Production Automation, and Manufacturing Processes) should be reorganized into five (5) product categories: Case Manufacture and Refurbishment, Insulated/Lined Segment, Propellant (Loaded Segment), Finished Segments and Igniter, and Nozzle. Each person would be responsible for the functional areas (processing, equipment, and tooling) of their product (fig. 13).

The reorganization of Productivity Engineering would assist in the teaming effort for the ASRM Project. Co-facilitators for the teams should be the representatives from the Design and Development and Productivity Engineering Groups. These teams should be supported with scheduling and SPC tools which provide visibility and accountability to product development, resources, MSFC support, and contractor interaction. Teaming would also allow the S&E Laboratories more visibility, participation into decisions, and alleviate some of the workload from the Chief Engineer's Office.



**Figure 13**

## TQM Systematic Recommendations—MSFC

### Specific MSFC Recommendations

1. Provide comprehensive TQM training.
2. Select new managers and partially executives based on their TQM track record.
3. Following center-wide training, benchmark the entire work force for TQM status.

During the course of implementing management programs such as TQM, the development of a supportive culture is usually neglected. This is a fatal mistake and usually serves as the genesis of another disappointing fad instead of a meaningful change. The following are the TQM recommendations expanded to serve as guidelines for core cultural change.

1. Broaden the TQM training curriculum to include behavioral sciences, ensuring that TQM training is comprehensive as figures 3 and 4 (pages 8 and 9) suggest. As the current curriculum appears tailored to the technical community, consider alternate tailoring for non-technical professionals. Comple-

tion of the TQM curriculum should be required before new managers assume supervisory responsibilities. Encourage managers to enroll in video-based graduate courses in Engineering Management.

2. The MSFC executive selection criteria currently contains a TQM category. Modify the criteria for executive management candidacy to include demonstration that the applicant actively contributes to a supportive cultural environment for TQM. Broaden the TQM category emphasis to include managers and select new managers based on knowledge and practice of TQM principles.
3. Reassess implementation status after the TQM training series and familiarization sessions. Survey entire work force using the original benchmark assessment format to determine if commitment is being communicated. All areas appear to be in the 2–2.5 range on a scale of 1–5 (Appendix G), which implies “average” in all areas. Reassessment after training may pinpoint areas that need more attention. A lower TQM implementation assessment rating may result as awareness becomes higher. This action will send a message to the work force that their opinion counts.

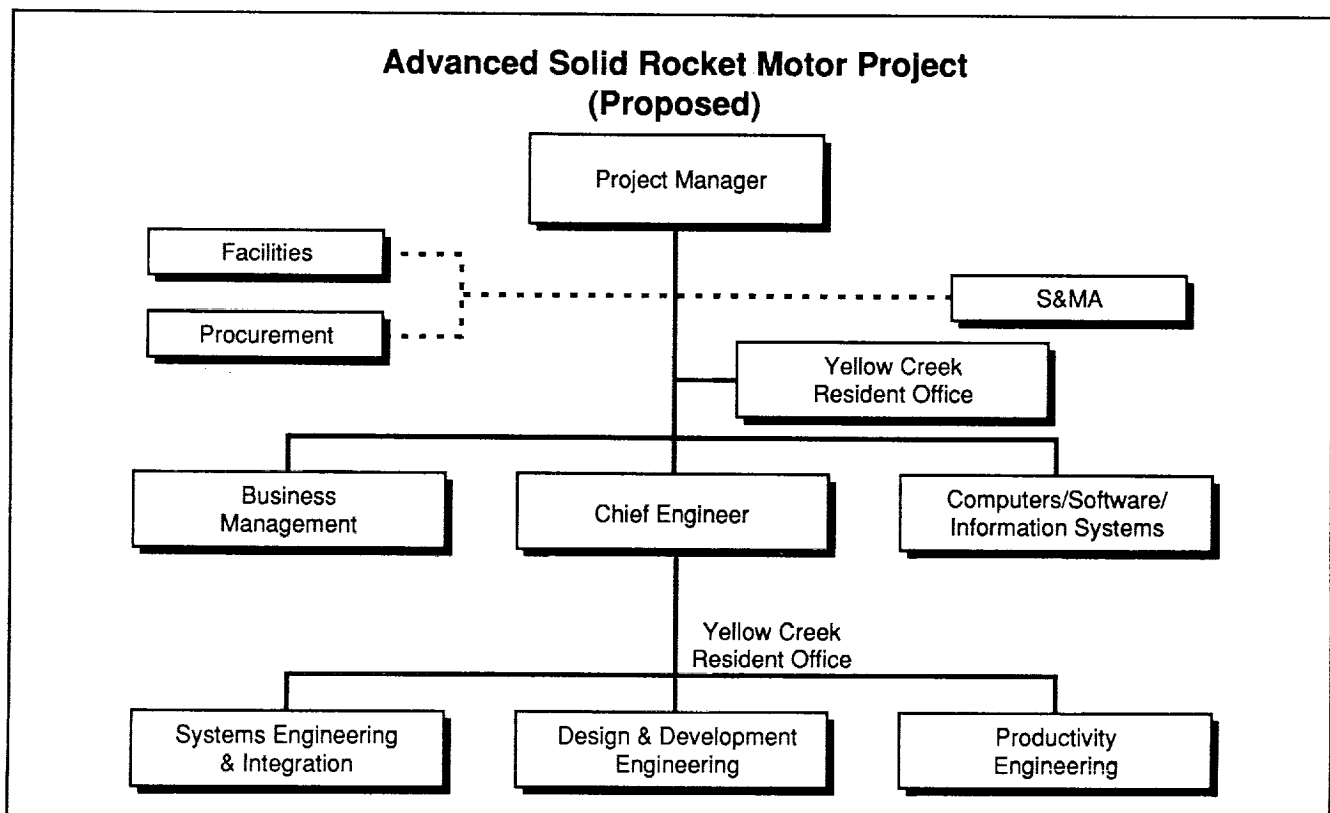


Figure 14

# mplementation Plan

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Based on the recommendations, the following specific actions are offered for the ASRM Project:

1. Immediately enroll all ASRM managers in comprehensive TQM training.
2. At course completion, initiate "Cascade Training" for the benefit of ASRM Project personnel.
3. In conjunction with the "Cascade Training," involve all ASRM employees in developing a vision statement and guiding principles.
4. Reassign Resident Chief Engineer and Computer/Information Systems person to recommended areas.
5. Begin forming teams as recommended, adding Productivity Engineering personnel as necessary and obtaining endorsement from supporting organizations.
6. Require teams to complete the team development training course that emphasizes group decision-making techniques.
7. Participatively establish goals, objectives and milestones for the pilot projects and prioritize sequence of activities.
8. Initiate team meetings with existing three Productivity Engineering personnel transitioning functional duties to team co-facilitators.
9. Continue forming teams with existing Productivity Engineering personnel until all teams are formed.
10. Establish decision criteria for transitioning pilot activity to full-scale implementation. ■



# Summary

TQM challenges norms. The newly formed ASRM Project has inherited a full set of norms from a long-standing and well-ingrained culture. ASRM, as any government program, lives by codes, regulations, and standards established by agencies outside NASA control. The ASRM Project is not like a new business started in a garage by an entrepreneur with a few good ideas. It is more like a newborn baby being assessed by grandparents. The child is determined to have eyes like the mother and feet like the father and other physical features like someone in the family. The child seems to have nothing of its own, much like the new ASRM Project.

TQM has great potential to improve almost all aspects of the MSFC culture thus impacting the ASRM operations. Although the bottom line impact on the ASRM cannot be accurately predicted, industries such as Xerox, IBM, GE and others herald the necessity of TQM.

The ASRM Project personnel previously worked in other areas and have seen management fads come and go. They currently have a very limited knowledge of TQM principles, but based on experience, they are skeptical as to its survival. Senior management promises commitment—just like the fads before TQM. The work force awaits the true indicators—culture change, improved systems, and people-oriented leadership.

Within a year TQM will reach that point in program maturity where other management philosophies lost

commitment and became fads. There are, however, several encouraging factors. Surveys and benchmarks are being used for self-evaluation, a critical component in the continuous improvement process. The entire work force at MSFC will receive some form of TQM training this year, demonstrating that management is willing to risk having a "TQM Literate" workforce watching their every move.

The ASRM Project has a unique opportunity to implement a TQM strategy more quickly and thoroughly than MSFC. The project has people with the right attitudes, personalities and management styles to naturally follow TQM principles. ASRM's success will have an impact on existing and future projects, making them "walk what they talk" on SPC, Theory Y management, and focusing on customer needs. ASRM's "petunia in the onion patch" could become less lonely over the next few years.

It is possible to effect a culture change at MSFC to implement TQM. The question remains as to the probability. Retirement attrition changes senior management every few years, changing priorities and commitment. If TQM is undertaken as an endeavor by the current senior management without commitment from the next four generations, TQM will fail. If on the other hand, TQM principles can become accepted for the next generations of management, it will survive the near term resistance to change and become the new norm. ■





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# A Walk Around the Space Shuttle

The Space Shuttle's superlative design provides capabilities and a flexibility unmatched by any other launch system. Here is what makes it work.

The Shuttle's major components are: the orbiter spacecraft; the three main engines, with a combined thrust of almost 1.2 million pounds; the huge external tank (ET) that feeds the liquid hydrogen fuel and liquid oxygen oxidizer to the three main engines; and the two solid rocket boosters (SRB's), with their combined thrust of some 5.8 million pounds, which provide most of the power for the first two minutes of flight.

The SRB's take the Space Shuttle to an altitude of 28 miles and a speed of 3,094 miles per hour before they separate and fall back into the ocean to be retrieved, refurbished, and prepared for another flight.

After the solid rocket boosters are jettisoned, the orbiter's three main engines, fed by the external tank, continue to provide thrust for another six minutes before they are shut down, at which time the giant tank is jettisoned and falls back to Earth, disintegrating in the atmosphere.

## The Space Shuttle Orbiter

The orbiter is both the brains and heart of the Space Transportation System.

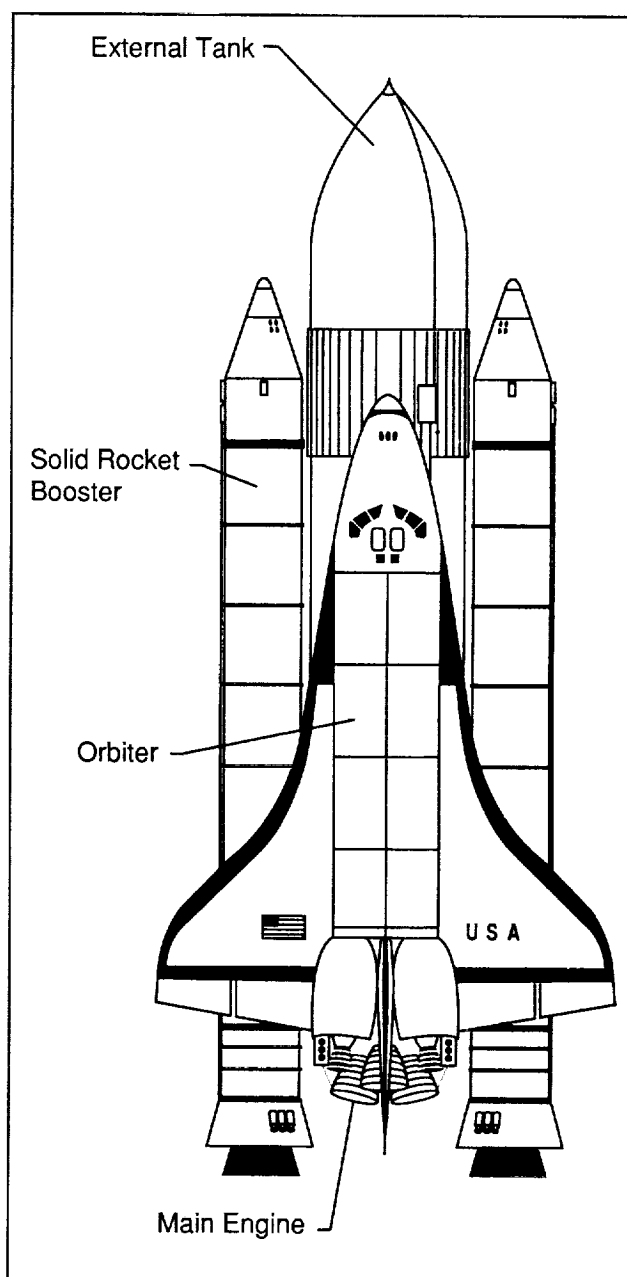
About the same size and weight as a DC-9 aircraft, the orbiter contains the pressurized crew compartment (which can normally carry up to seven crew members), the huge cargo bay, and the three main engines mounted on its aft end.

The thermal tile system, which protects the orbiter during its searing reentry through the atmosphere, was a breakthrough technology that proved much more challenging than expected.

There are three levels to the crew cabin. Uppermost is the flight deck where the commander and the pilot control the mission, surrounded by an array of switches and controls. During the launch of a seven-member crew, two other astronauts are positioned on the flight deck behind the commander and pilot. The three other crew members are in launch positions in the mid-deck, which is below the flight deck.

The mid-deck is where the galley, toilet, sleep stations, and storage and experiment lockers are found for the

basic needs of weightless, daily living. Also located in the mid-deck are the side hatch for passage to and from the vehicle before and after landing, and the airlock hatch into the cargo bay and space beyond. It is through this hatch and airlock that astronauts go to don their spacesuits and manned maneuvering units (MMU's) and prepare for extravehicular activities (EVA's), more popularly known as "spacewalks." These excursions have produced some of the most important space firsts in the Shuttle program as well as the most spectacular photographic vistas of the space age. Below the mid-



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deck's floor is a utility area for the air and water tanks and their ducts.

The Space Shuttle's cargo bay is adaptable to hundreds of tasks. Large enough to accommodate a tour bus, (60 × 15 feet) the cargo bay instead carries satellites, spacecraft, and Spacelab scientific laboratories to and from Earth orbit. It is also a work station for astronauts to repair satellites, a foundation from which to erect space structures, and a hold for retrieved satellites to be returned to Earth.

Mounted on the port side of the cargo bay behind the crew quarters is the remote manipulator system (RMS). The RMS is a robot arm and hand with three joints analogous to those of the human shoulder, elbow, and wrist. It is operated from the aft station of the orbiter's flight deck. The RMS, some 50 feet long, can move anything from satellites to astronauts to and from the cargo bay or to different points in nearby space.

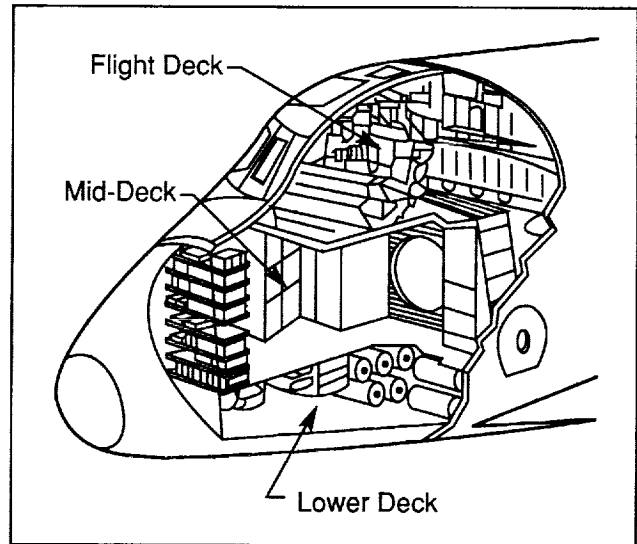
Thermal tile insulation and blankets (also known as the thermal protection system or TPS) cover the underbelly, bottom of the wings, and other heat-bearing surfaces of the orbiter and protects it during its fiery reentry into the Earth's atmosphere.

Designed to be used for 100 missions before replacement is necessary, the Shuttle's 24,000 individual tiles are made primarily of pure-sand silicate fibers, mixed with a ceramic binder. Incredibly lightweight, about the density of balsa wood, they dissipate the heat so quickly that a white-hot tile with a temperature of 2,300 degrees Fahrenheit can be taken from an oven and held in bare hands without injury.

## The Main Engines and Orbital Propulsion Systems

The three main engines are clustered at the aft end of the orbiter and have combined thrust of almost 1.2 million pounds at sea level. They are high performance, liquid propellant rocket engines whose thrust can be varied over a range of 65 to 109 percent of their rated power level. They are the world's first reusable rocket engines, designed to operate for 55 flights, and are 14 feet long and 8 feet in diameter at the nozzle exit.

Two orbital maneuvering system (OMS) engines, mounted on either side of the upper aft fuselage, provide thrust for major orbital changes. For more exacting motions in orbit, forty-four small rocket engines, clustered on the Shuttle's nose and on either side of the tail, are used. Together they are known as the



reaction control system and are used to aid in retrieving, launching, and repairing satellites in orbit.

## The External Tank

The giant cylinder, higher than a 15-story building, with a length of 154 feet, and as wide as a silo with a diameter of 27.5 feet, is the largest single piece of the Space Shuttle. During launch, the external tank also acts as a backbone for the orbiter and solid rocket boosters to which it is attached.

In separate pressurized tank sections inside, the external tank holds the liquid hydrogen fuel and liquid oxygen oxidizer for the Shuttle's three main engines. During launch, the external tank feeds the fuel under pressure through 17-inch ducts which branch off into smaller lines that feed directly into the main engines. Some 64,000 gallons of fuel are consumed by the main engines each minute.

Machined from aluminum alloys, the Space Shuttle's external tank is the only part of the launch vehicle that currently is not reused. After its 526,000 gallons of propellants are consumed during the first eight and one-half minutes of flight, it is jettisoned from the orbiter and breaks up in the upper atmosphere, its pieces falling into remote ocean waters.

## The Solid Rocket Boosters

The Space Shuttle's two solid rocket boosters, the first designed for refurbishment and reuse, are also the largest solids ever built and the first to be flown on a manned spacecraft. Together they provide the majority of the thrust for the first two minutes of flight—some 5.8 million pounds.

The solid propellant mix is composed of 16 percent aluminum powder (fuel) and almost 70 percent ammonium perchlorate (oxidizer), with the remainder made up of a binder, a curing agent, and a small amount of

catalyst. A small rocket motor in each booster ignites the propellant at launch. During flight, the solid booster nozzles swivel up to six degrees, redirecting the thrust and steering the Space Shuttle toward orbit. ■

## ASRM Design

### Insulation

- Uses Improved RSRM J-Seal Design at Field Joint
- New Castable Inhibitor-to-Stress Relief Flap Joint Location Minimizes Potential for Jetting Into Sidewall Insulation
- Asbestos-Free Formulation

### Nozzle

- Reduces Number of Flame and Nonflame Insulator Joints
- Eliminates 72 Stat-O-Seals and Associated Leak Paths

### Case

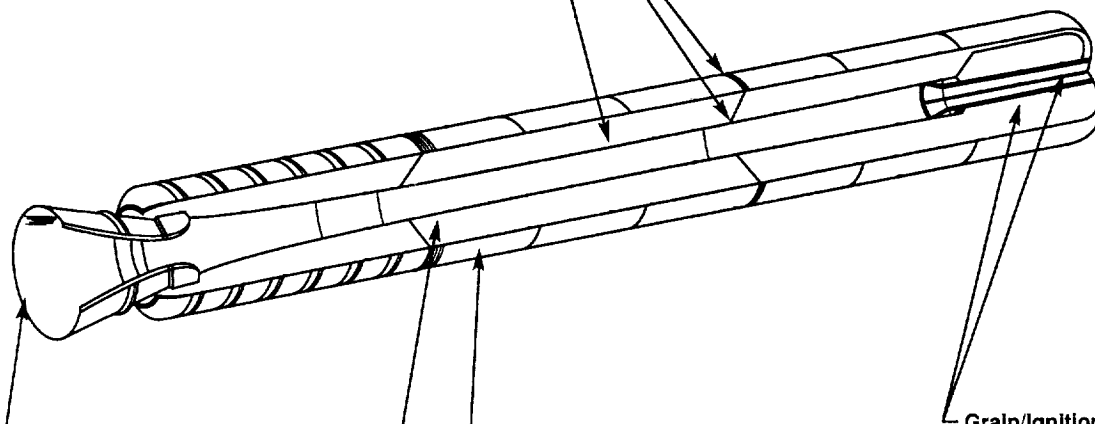
- Eliminates One Field Joint
- Superior Fracture Toughness
- Higher Stress Corrosion Resistance
- Welded Factory Joints
- Integral Stiffeners and ET Attach Ring in Aft Segment Eliminates Failure Points Experienced With Bolt-On Stiffeners and Ring

### Propellant

- Industry-Proven HTPB Propellant with over 60M lbs Successfully Produced
- Formulated and Proven for Continuous Mix Process
- Density Impulse Increased 24 Percent Versus RSRM Propellant
- High Positive Margins Under All Required Conditions

### Grain/Ignition

- Safety Margin in Forward Fin Trailing Edge Nearly Doubled
- Igniter Design Eliminates 32 Chamber Bolt Leak Paths
- Expendable Carbon Filament Chamber
- TBI Initiator Eliminates S&A Device Leak Paths



Courtesy of Lockheed Gencorp Aerojet Space Boosters





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**Appendix**

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**B**

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EXECUTIVE OFFICE OF THE PRESIDENT  
OFFICE OF MANAGEMENT AND BUDGET  
WASHINGTON, D.C. 20503

**DRAFT**

DATE \_\_\_\_\_

CIRCULAR A-\_\_\_\_\_

TO THE HEADS OF EXECUTIVE DEPARTMENTS AND ESTABLISHMENTS

SUBJECT: Improving the Quality of Government Products and Services

1. Purpose. This circular provides guidance for developing and maintaining high-performing executive agencies that continuously improve the quality of their products and services and the efficiency of the processes that produce them. The guidance contained herein is a natural extension and refinement of the government-wide effort, begun in 1986, to improve quality and productivity in Federal agencies.

2. Authority. Executive Order 12637 provides authority for the establishment of quality and productivity improvement efforts in executive departments and agencies. The Executive Order places overall direction of this effort with the Office of Management and Budget (OMB) and authorizes the Director to set goals, policies, standards, and guidelines for the administration of the order.

3. Policy. Federal agencies are expected to make continuous, incremental improvement in the quality, timeliness, efficiency, and effectiveness of their products and services by implementing Total Quality Management (TQM) practices. The TQM approach incorporates all of the key features for achieving high performance in organizations and achieving quality results, i.e., delivering products and services that are responsive to customer requirements, achieve their intended purpose, and make effective use of taxpayer dollars.

4. Scope and Applicability. This circular applies to the executive agencies listed in Attachment A.

5. General Definitions. The following definitions are used in relation to quality and productivity improvement:

Total Quality Management (TQM): a total, integrated organizational approach for meeting customer needs and expectations that involves all managers and employees and uses quantitative methods and employee involvement to improve continuously the organization's processes, products and services.

Customer: the persons or groups within the organization for whom intermediate products or services are provided (internal customers); the persons or groups outside the organization for

whom final products or services are provided (external customers).

Supplier: the persons or groups within the organization who provide input (e.g., information, material) to internal customers (internal suppliers); the persons or groups outside the organization who provide input (e.g., information, material) necessary to produce goods or deliver services (external suppliers).

Quality: the extent to which products or services meet customer requirements and expectations.

Productivity: the efficiency with which resources are used to produce a product or provide a service.

Timeliness: the promptness with which products and services are delivered, relative to customer requirements and expectations.

Effectiveness: the extent to which a product or service delivered to a customer achieves its intended purpose.

Process: the transformation of input through a series of activities that use people, materials, methods (including machines) to produce a product or provide a service for a customer.

Agency: the five independent agencies listed in Attachment A and the major components of the 14 Cabinet Departments.

6. Total Quality Management. TQM is a comprehensive management approach for achieving high performance and improving quality by examining in a systematic manner, throughout the whole organization, methods by which work gets done. The focus is on increasing value to the customer by ensuring that all work processes efficiently and effectively provide the service that customers want.

Organizations in both the private and public sectors that have adopted the TQM approach consistently increase value to customers, improve productivity, reduce total costs, improve products and services, achieve better planning and forecasting, reduce administrative overhead, reduce rework and waste, and improve employee performance and morale. Businesses in the private sector that have won the Malcolm Baldrige National Quality Award have employed TQM practices. The application of TQM can help to resolve some of the problems which pose major challenges for Federal agencies -- public image, cost efficient products, competitiveness, and bureaucratic impacts on customers.

Two conditions are essential for the success of TQM in any organization: leadership commitment and education and training. TQM cannot be instituted by groups external to line management. Although quality offices exist, they best function as advisors. Top managers must be committed to quality improvement and motivate their mid-level managers and employee to achieve improvement in the organization. Education and training in quality techniques and problem-solving skills are needed to analyze processes and design improvements. Without top management leadership and an extensive training effort, other TQM practices will not take root.

Quality improvement under TQM also emphasizes: a) the avoidance of rework due to errors, unclear procedures or other causes; b) continuous examination of procedures and processes to improve the quality of outputs and the efficiency of work; c) the elimination of work that adds no overall value; and d) continuous reduction in the cycle time required for providing services. TQM is a dramatic departure from traditional "quality control" programs which focused only on accepting or rejecting final outputs at the end of the process. Resources saved by "doing the right thing right the first time" results in improved efficiency and better service to the public. Productivity is an expected outcome of quality and a necessary companion to improving service.

TQM requires a long-term commitment to ensure that the desire for excellence is deeply embedded in the organization and that improvements in service will be continuous. Experience indicates that changing the culture of an organization requires time and determination on the part of top management. The work environment must place a premium on quality, build structures that will sustain change and provide education to support the effort. Some results will be immediate and many will be incremental, but others may take several years to achieve.

TQM involves top executives, managers, union leadership, and employees together in creating a culture of excellence that emphasizes:

- o Top management leadership and support
- o Strategic planning and implementation geared to long-term success
- o Focus on the customer
- o Commitment to training and recognition
- o Employee empowerment and teamwork
- o Reliance on measurement and analysis of processes and outputs
- o Quality assurance

A more complete description of TQM is contained in Attachment B.

7. Agency Responsibilities. Agency heads are responsible for achieving the objective of this governmentwide effort: to make continuous, incremental improvement in the quality, timeliness, efficiency, and effectiveness of products and services by implementing TQM. TQM should be implemented throughout the agency, since it is a total management system that applies to all levels, all functions, all services, and all employees.

Agency heads and their top management teams should be directly and actively involved in the implementation of TQM (see Attachments B and C). This responsibility is integral to line operations, critical to the success of TQM, and cannot be delegated. Top management must make a long-term commitment and provide constancy of purpose toward long-range goals.

It should be noted that agencies are in different stages of implementing TQM. Many have not yet begun, others are in the planning stages, some have just begun to implement, and a few are in their second, third or fourth year of implementation. Because of these variances and diverse stages of readiness for change, as well as dissimilar organizational cultures, external environments, management styles and characteristics of programs and services, agencies are not expected to implement TQM in lockstep, and will not be compared to other agencies. Rather, each agency is expected to proceed at its own pace, but should demonstrate progress against its own past record. For agencies just starting to implement TQM, some reasonable expectations for the first year of implementation are described at Attachment E.

Agencies are strongly encouraged to share information on TQM implementation (e.g., training materials) with other agencies, especially small agencies (e.g., through the Small Agencies Council) and to form information-sharing networks in similar program activities.

A. Reporting Progress to the Administration.

1) Report on the implementation of TQM. Each year agencies (see definition on page 2) should review their progress in implementing TQM. The annual review of progress may be conducted either formally or informally at an agency's discretion. For example, a formal review might take the form of an organizational self-assessment using a diagnostic survey instrument (e.g., Department of Defense's Quality and Productivity Self-Assessment Guide), an assessment of TQM by a team of management analysts or by a team of managers from inside and outside the agency. An informal review might consist of reliance on regularly reported information to the agency's Quality Council (or Policy Board) from all parts of the agency. Whether the review is conducted formally or informally, the agency should make every effort to ensure its accuracy by soliciting the views of various groups (e.g., employees, unions,

customers, suppliers) on relevant issues. If conducted carefully, the review should become an instrument for planning improvements.

Following the annual review of progress, agencies should use Attachment C, "A Description of Various Phases of TQM Implementation in an Organization" to determine which phase in each of the seven basic TQM elements best describes their level of implementation. These results should be reported to OMB by March 31 each year beginning in 1991, using the format at Attachment D, pages 1, 2, and 3.

Because only six phases of implementation are described for each TQM element in Attachment C, it is likely that an agency will not move through a phase each year. Movement to a new phase each year would mean advancing from non-involvement in TQM to a world-class quality organization in six years, a highly unlikely feat. The reporting format at Attachment D, therefore, provides a page to list significant actions taken during the year. Thus, progress in implementing TQM that may not be apparent from examining the phases of implementation can be captured in this narrative format.

2) Report on the quality, timeliness, efficiency and effectiveness of key products/services. A report, using pages 4, 5, and 6 of Attachment D, should be sent to OMB by March 31 each year beginning in 1992. This time lag in reporting performance data should give agencies sufficient time to develop performance indicators. For agencies just beginning to implement TQM it is more important to advance the TQM process and wait to tackle the measurement issue at the appropriate implementation phase. This will occur only after identifying customer requirements and building those into the measurement system.

Those agencies which have already identified the customers of their key products and services, know customer requirements, translated those requirements into indicators of quality and timeliness, and tracked their efficiency and effectiveness, may wish to report all or some of this information in 1991. Many agencies have already developed good quality, timeliness, and efficiency measures as part of their past quality and productivity improvement efforts and these measures could continue to be used. For 1991, however, this report is optional.

The products and services to be reported on will be worked out between each agency and OMB during 1990. Program functions previously included in each agency's quality and productivity program inventory will serve as a starting point of discussion. Primary consideration will be given to products and services that consume a significant part of an agency's resources and/or

provide an important service to the agency's customers or the general public.

Any agency which applies for the Quality Improvement Prototype Award or the President's Award for Quality need not submit an annual report for the year in which an award application is submitted, since the information will be duplicative.

B. Coordination of TQM Implementation. The head of each agency listed in Attachment A is responsible for ensuring that all components are implementing TQM and should appoint a personal representative of sufficient stature to coordinate this effort. This senior official will also serve as the key contact point between the agency and OMB. OMB's Assistant Director of General Management will meet with the TQM coordinators on a quarterly basis to exchange information, discuss policy, progress, and any problems that occur.

C. Formation of Executive TQM Networks. During 1990, OMB will work with the TQM Coordinators to establish several Executive TQM Networks of senior-level line managers from the major bureaus, services, commands. Each network will consist of key line managers (not staff) performing similar functions; e.g., health care, social services, research, investigations. A list of functional categories is at Attachment F.

The primary purpose of each Executive TQM Network is information exchange. Bringing together several senior-level managers involved in similar operations but at different levels of TQM implementation is a technical assistance device of minimal cost and high potential benefit. The network can provide an opportunity to exchange ideas and discuss lessons learned from those farther advanced in TQM. As a forum of functional experts with credibility in the eyes of their peers, it can foster an ongoing dialogue about TQM and facilitate its implementation.

8. Role of OMB. OMB is responsible for: a) providing policy guidance and coordination for the government-wide effort; b) working with agencies, the PCMI, and other outside groups to provide the types of assistance described in Attachment G; c) creating an atmosphere of positive reinforcement for TQM implementation; and d) monitoring agency progress in achieving the goals of TQM.

OMB will expand its assistance into two new areas beginning in 1990. The first is arranging for and coordinating on-site quality reviews. These reviews, which will assess the status of TQM implementation in agencies, will be conducted by small teams of public and private sector managers who are implementing TQM in their own organizations. The reviews will be conducted only at



the request of an agency. OMB will tap various quality and productivity associations, its 18 member TQM Advisory Group and other private and public sector contacts to arrange for an appropriate team to conduct the quality review. Costs for travel will be shared by the requesting agency and the team of review participants. OMB will work out all details of the quality review with the requesting agency, including the level of OMB's participation. The advantages of a quality review are several. It can provide a benchmark of agency progress, clarify goals the agency can strive for in the future, identify new ideas for action based on the collective experience of the review team, and provide an opportunity for managers to discuss candidly their strengths and areas for improvement with an outside, objective group.

The second area of assistance will consist of initiating with the President's Council on Management Improvement (PCMI) several pilot projects for de-regulating agencies to improve service delivery. The projects are intended to create an environment where managers close to the point of service delivery have greater decision-making authority and more control over their resources. The experiments will relax regulations in the areas of budgeting, procurement, personnel and administrative policies, thus creating greater flexibility. At the same time accountability will be maintained through results-oriented performance measures in the areas of quality, schedule, cost, effectiveness, and integrity. The experiments, if successful, will be expanded to larger segments of government and facilitate the implementation of TQM.

9. Role of the PCMI. The PCMI, representing the participating agencies, plays a leadership role in the implementation of the government-wide effort to improve quality and productivity. The PCMI, through its various committees, works with OMB in carrying out the projects described above and in Attachment G. In addition, it undertakes other projects to support and reinforce TQM, such as publicizing exemplary practices and assisting agencies to mount similar activities. The PCMI also provides recommendations to OMB and the agencies for improving and strengthening government-wide quality and productivity in service delivery.

10. Role of the Office of Personnel Management (OPM). OPM is responsible for: a) reviewing and recommending appropriate revisions of personnel policy and practices currently in effect to support and facilitate agency implementation of TQM (e.g., areas of possible change might include classification, incentive practices, delegations of authority, performance appraisal); b) developing and issuing materials on selected topics, such as incentives and position management, to assist agencies in carrying out flexible personnel practices; c) developing and implementing education and training programs for Federal

employees on TQM.

11. Federal Quality Institute (FQI). Established in 1988 as part of the government-wide effort to improve quality and productivity, the FQI has three major purposes:

1) Provide quality awareness seminars and follow-up assistance to top policy officials and senior executives to encourage management understanding of and commitment to TQM;

2) Assist agencies to implement TQM by providing them with a roster of qualified private sector consultants through a Federal Supply Schedule contract; and

3) Provide information to agencies on improving quality and productivity by operating a resource center that serves as a TQM clearinghouse and referral service.

The FQI is a primary vehicle of information, training, and consulting services available to agencies on the subject of Total Quality Management. Agencies are encouraged to use its expertise and resources. FQI can be reached by calling (202) 376-3751.

12. Effective Date: This circular is effective upon publication and rescinds Circular A-132, dated April 22, 1988.

13. Sunset Date: This circular shall have an independent policy review to ascertain its effectiveness three years after its issuance.

14. Inquiries: Any questions regarding this circular should be directed to the Quality Management Branch at (202) 395-3692.

Richard Darman  
Director

Attachments

EXECUTIVE AGENCIES INCLUDED IN THIS CIRCULAR

Department of Agriculture

Department of Commerce

Department of Defense

Department of Education

Department of Energy

Department of Health and Human Services

Department of Housing and Urban Development

Department of the Interior

Department of Justice

Department of Labor

Department of State

Department of Transportation

Department of the Treasury

Department of Veterans Affairs

Environmental Protection Agency

General Services Administration

National Aeronautics and Space Administration

Office of Personnel Management

United States Information Agency



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**Appendix**

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**C**





# Management Instruction

NMI 1270.2

Effective Date February 1, 1990

Expiration Date February 1, 1990

Responsible Office: Q/Safety, Reliability, Maintainability and Quality  
Assurance (SRM&QA)

Subject: AGENCYWIDE TOTAL QUALITY MANAGEMENT

1. PURPOSE

This Instruction establishes the NASA policy and responsibilities for agencywide Total Quality Management (TQM).

2. APPLICABILITY

This Instruction applies to field installations and NASA Headquarters.

3. BACKGROUND

First and foremost it must be stressed that the primary purpose and objective of TQM is the achievement of mission success in every activity that NASA does, whether it is programmatic, research, administration, services or support. Since 1982 NASA has had an active Quality and Productivity Improvement (Q/PI) program. This ongoing NASA adaptation of TQM fosters improved quality and productivity among both the civil servant and the contractor work forces. It has been particularly proactive in the external arena with programs like the NASA Excellence Award for Quality and Productivity and the annual contractors conferences and symposia. In the ensuing years, Executive orders have mandated that Federal agencies demonstrate a measurable increase in the quality of goods and services and the productivity of the Federal work force. To attain the latter end, NASA will pursue vigorous proactive internal initiatives to conform to the spirit and requirements of the Executive orders and Office of Management and Budget directives and bulletins.

4. POLICY

- a. Each installation and the Headquarters will develop and actively pursue an approach to TQM based on elements from two productivity publications, the "Strategies for Revitalizing Organizations," dated August 1987 and "NASA/Contractor Team - Summary of Strategies for Planning Productivity Improvement and Quality Enhancement (PIQE)" dated April 1986. Ten basic tenets will be stressed:

- (1) Top management to provide leadership, personal involvement, and long-term commitment.
  - (2) Set team goals and promote world class levels of quality and performance.
  - (3) Support new technology and modernization in the organization.
  - (4) Create an innovative and challenging team climate.
  - (5) Use participative management techniques to increase individual/team contributions.
  - (6) Develop effective communications among employees, contractors, and customers.
  - (7) Stimulate and promote individual involvement.
  - (8) Commitment to education and training.
  - (9) Develop and implement means to evaluate and measure team performance.
  - (10) Focus on the customer.
- b. Each installation and the Headquarters' management is responsible and accountable for developing and implementing those actions required to meet the intent and goals of the two cited documents referenced in paragraph 4a. Each installation and the Headquarters will have a minimum of two long-term goals with measurable results, that respond to the President's initiative, and a like number of short-term goals each year that focus on the customer. To enhance teamwork and esprit de corps, each installation's and the Headquarters' yearly performance will be assessed and a NASA Administrator's Excellence Award for Quality and Productivity will be awarded for the best performance.



## 5. RESPONSIBILITIES

The implementation of TQM is the responsibility of all NASA employees. Specifically:

- (a) The Administrator, Associate Administrators, other Officials-in-Charge of Headquarters Offices, and the Field Installation Directors are responsible for providing executive leadership and overall direction to integrate a TQM philosophy. This group will also function as the TQM Steering Committee.
- (b) Managers and supervisors are responsible for developing a positive climate for TQM and are accountable for communicating clear goals, focusing on mission success, and encouraging employee participation.
- (c) Each installation and the Headquarters, as an operating entity, will provide a yearly plan that meets the intent of publications referenced in paragraph 4 and associated Executive orders.
- (d) Each installation and the Headquarters, as an operating entity, will identify "TQM" focal point. These individuals will function as the TQM working team to provide coordination of related activities and interchange of ideas.
- (e) Employees are responsible for carrying out the work and making suggestions for work improvements to enhance the quality of work and work life and, in turn, their own performance.
- (f) The responsibility for overall administration and reporting for the agency program will be the Office of Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA), Code Q.

6. REPORTING

The responsible officials will ensure reports are rendered and feedback provided to keep the Administrator fully and currently informed of significant actions and other matters of substance related to the provisions hereunder.



Administrator

DISTRIBUTION:

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## Appendix **D**

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MANAGEMENT  
ANNOUNCEMENT

NASA  
National Aeronautics and  
Space Administration

George C. Marshall Space Flight Center  
Marshall Space Flight Center, Alabama 35812

Originating Organization: DX01	Effective Date: MAY 18 1990	MA 1150.1A
	Expiration Date: Effective until rescinded	Control No.:

Subject: MSFC Continuous Process Improvement Steering Council (CPI)

1. MEMBERSHIP

The following individuals are hereby appointed to the MSFC Continuous Process Improvement Steering Council.

Chairperson

T. J. Lee, DA01

Alternate Chairperson

J. W. Littles, DD01

Members

J. A. Bethay, DE01

G. F. McDonough, EA01

R. G. Sheppard, AA01

H. W. Hallisey, BC01

C. D. Bean, CO01

S. P. Saucier, FA01

J. W. Littles, HA01

H. G. Craft, Jr., JA01

G. D. Hopson, KA01

C. R. Darwin, PA01

G. P. Bridwell, SA01

F. S. Wojtalik, TA01

2. REFERENCE

NMI 1270.2, "Agency-Wide Total Quality Management," dated February 1, 1990.

MM 1150.1A, Charter 3-30, "MSFC Continuous Process Improvement Steering Council," dated

Original signed  
by  
T.J. LEE

T.J. Lee  
Director

Distribution:

SDL 1

All persons listed

MSFC-Form 2913 (Rev. July 1979)

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# C H A R T E R

N A S A

National Aeronautics and  
Space Administration

George C. Marshall Space Flight Center  
Marshall Space Flight Center, Alabama 35812

MSFC CONTINUOUS PROCESS IMPROVEMENT STEERING COUNCIL (CPI)	MM 1150.1A	Charter Number: 3-30
	Effective Date: MAY 18 1990	

## 1. PURPOSE

To provide guidance, motivation, and oversight to the Center's implementation of Continuous Process Improvement (CPI); to develop and maintain the long-range process improvement plan establishing appropriate goals for the Center; and to ensure a practical and effective CPI effort for the Center.

## 2. SCOPE

The CPI Steering Council will ensure CPI methods are implemented and monitored within Center organizations, component installations, and contracted efforts as deemed appropriate.

## 3. DEFINITION

Continuous Process Improvement is a management philosophy/operating methodology totally committed to:

- Continuing improvement of all processes and products.
- Satisfaction of internal and external customer needs.
- Universal participation and teamwork.

## 4. POLICY

Pursuit of excellence through continuous improvement of products and processes is a primary goal of the Marshall Space Flight Center. The CPI Steering Council will be the guiding body for all efforts embodying the CPI philosophy/methodology. Existing organizations will prepare for and carry forward with CPI within their areas. Cross functional teams will be utilized for study/improvement of processes which cut across organizations and functions.

5. RESPONSIBILITIES

- a. Development of a long range plan for CPI efforts at MSFC and establishment of goals.
- b. Oversight and guidance to implementation of CPI.
- c. Review of CPI efforts and results.

6. AUTHORITY/REFERENCE

NMI 1270.2, "Agency-Wide Total Quality Management," dated February 1, 1990.

7. FREQUENCY OF MEETINGS

The CPI Steering Council will meet as required.

Original signed  
by  
T.J. LEE  
T. J. Lee  
Director

Distribution:

SDL 1

All persons listed

MSFC - Form 3074 (Rev. July 1979)





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# Appendix

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# ASRM Project Continuous Improvement Plan

By:

J.W. Thomas

Vice President, ASRM Project Manager

C.T. Levinsky

President, Aerojet ASRM Division



## 1.0 Introduction

This plan applies specifically to the operations of the ASRM project. It is our plan to create and sustain an environment that fosters continuous improvement. The continuous improvement process is dedicated to the principles of Total Quality Management (TQM). This plan will outline the key elements in developing, implementing, and following through with a TQM and Continuous Improvement program.

Using systematic tools from the design and development phase through characterization, verification, control and process improvement phases; we have the unique opportunity of establishing an effective Continuous Improvement Program from the project's initiation.

## 2.0 Approach

The ASRM project's foundation is based on TQM and Continuous Improvement. Our approach starts with

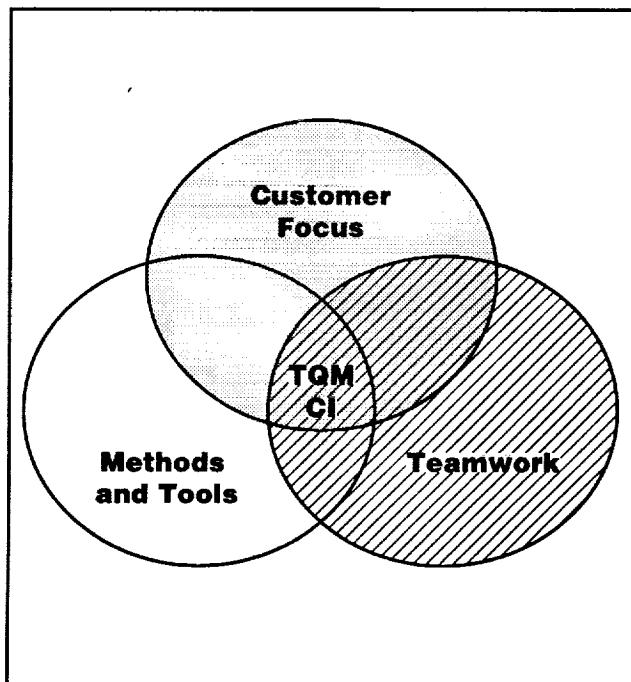


Facing Northwest, the ASRM Yellow Creek  
Production Facility, Near Iuka, Mississippi

management commitment, beginning with the ASRM Project Manager, and focuses on involvement of all ASRM employees. This approach is expected to result in improved quality, reliability, cost and schedule performance. The purpose of continuous improvement is to provide the customer with an improved product and service.

The ASRM approach consists of the following:

- Top management commitment and leadership
- Product development teams
- Group participation in the design, development and implementation processes
- Identification of customer and customer needs
- Promotion of individual involvement
- Means to evaluate, measure, and report improvement
- Training and education of systematic tools
- Recognition of accomplishment
- Employee awareness
- Partnership with subcontractors.



## 3.0 Mission/Objective/Goals

### 3.1 Mission

The ASRM mission:

“Provide quality products, services, and system management to the ASRM project.”

Quality refers to the competitive way we price our product and services, the way we meet the customer’s needs in providing the product or service and the timeliness with which we do it. Nothing short of customer satisfaction will allow us to fulfill our mission.



The Sun Sets on the 60-foot TVA Cooling Tower Foundation at Yellow Creek

### 3.2 Objective

The ASRM project objective reflects the way we will operate to accomplish our mission. Our objectives are:

- To embrace the principles and practices of good process management
- For all employees to participate on a daily basis to identify and eliminate waste from the processes
- For management at every level to become coaches and mentors, empowering, enabling, and entrusting fellow employees to improve the way we operate
- For all employees to be knowledgeable in the use and application of systematic tools for continuous improvement

- For all employees to know who “their” customers are, both internally and externally
- For a communication network whereby every employee will know his/her customers’ needs and will apply the tools of process improvement to ensure that these needs are met.

### 3.3 Goals

Our goals for Continuous Improvement are to achieve a level of understanding whereby:

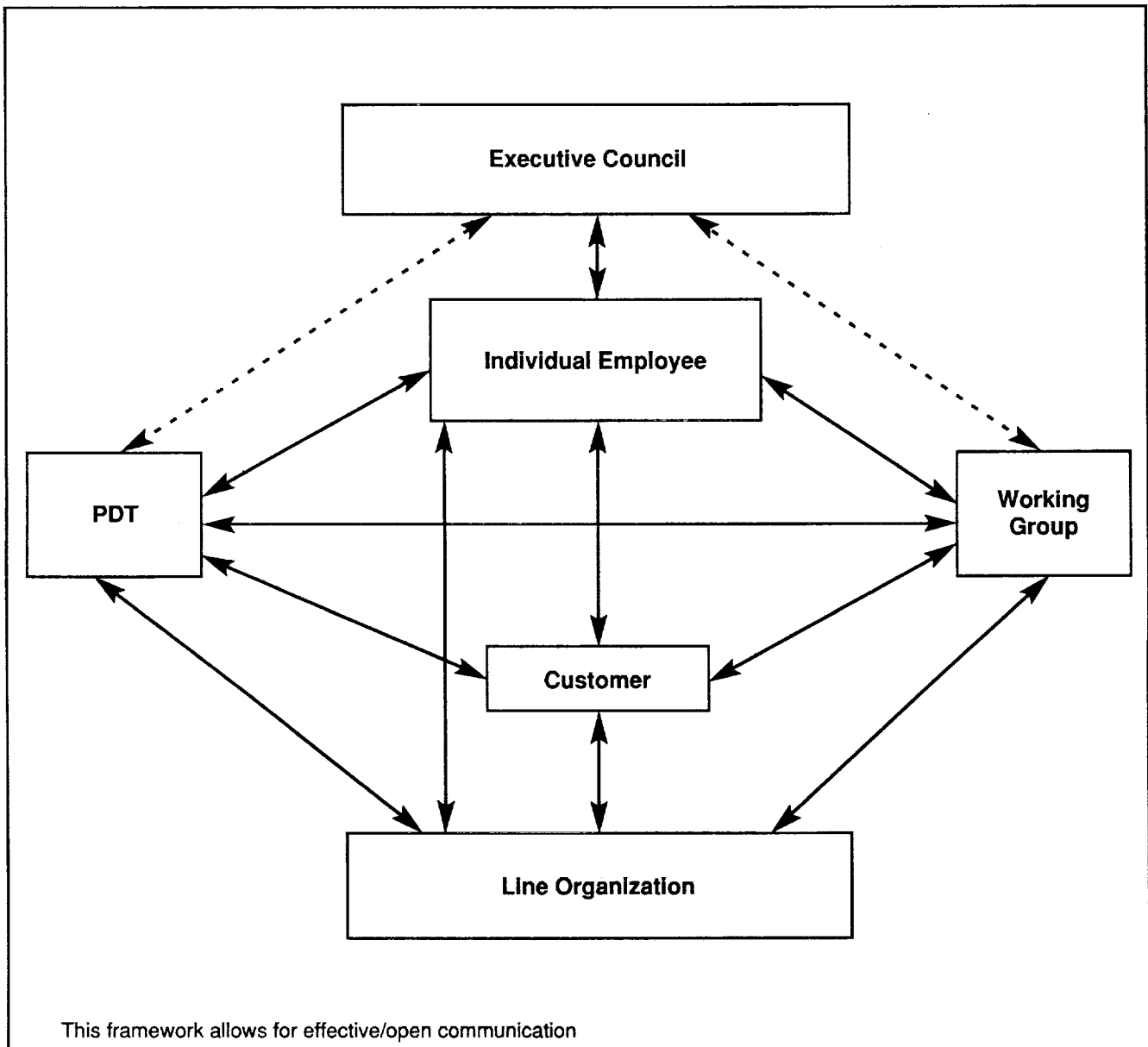
- All employees embrace the process of Continuous Improvement
- All employees feel free to identify inefficiencies

- A level of customer satisfaction (internal and external) is achieved that will cause customers to commend the successful outcome of our processes and increase their demand for our products and services.

## 4.0 Framework

### 4.1 Executive Council

The Executive Council is composed of the ASRM Project Manager (Chairman), Deputy Project Manager, President of Aerojet ASRM Division, Executive Vice-President of Aerojet ASRM Division, and four additional members selected at large.



The purpose of the Executive Council is to provide guidance, implementation and awareness throughout all levels of the organization, and to measure/track progress.

#### **4.2 Functional/Department Staff Meeting**

There are eleven ASRM functions. The functions are Safety, Reliability, Maintainability, and Quality Assurance; Facilities; System Engineering & Integration; Program Management & Control; Support Equipment; Design Engineering; Manufacturing; Quality Assurance; Test Operations; Subcontract Performance, and Project Planning & Control. The staff meetings are one arena for updating all department employees on ongoing issues. This allows for input from co-workers as to possible solutions to issues.

#### **4.3 Product Development Team (PDT)**



The PDT is one method we have employed to ensure success of the ASRM team approach. The PDT is composed of representatives from all functions, as well as representatives from subcontractors (Aerojet ASRM Division, Thiokol, and B&W). Each PDT holds regularly scheduled meetings and is managed by selected individuals from the Lockheed/Aerojet Team. The PDT is a:

- Multi-organizational participation in design effort
- Arena for knowledge in the use and application of systematic TQM tools
- Way of providing a communication network for knowing the customer (internal and external) and his/her needs

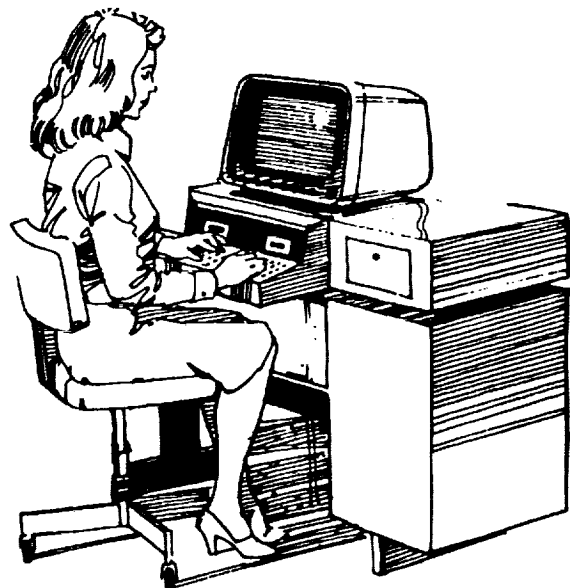
#### **4.4 Working Group**

A working group can be a subgroup of a PDT or functional organization that focuses on an issue, searches for solutions and reports weekly. The working group membership can be functional or cross functional lines. The working group will generally be a group of five or six members with knowledge of the particular issue being worked.

#### **4.5 Individual Employee**



Management must entrust individual employees by encouraging them to recommend changes to improve their work processes. The individual employee must be given the opportunity to suggest possible process improvements and feel confident in doing so.

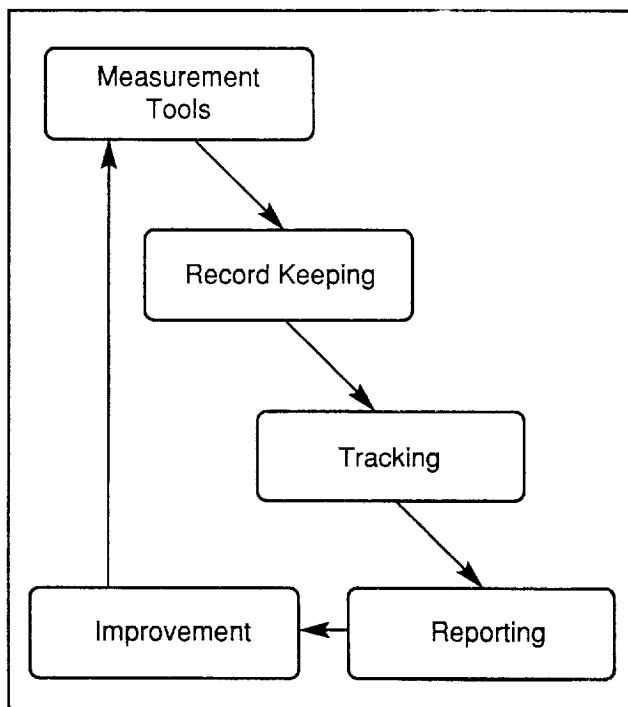


## 4.6 Customer

Our customer may be identified as an internal organization of the ASRM project as well as our contractual customer. Since the focus of this entire plan is to meet customer's needs, it is appropriate that our customer is included in this team approach. We will continue to solicit customer participation in our continuous improvement process in order to respond quickly to changing needs.

## 5.0 Measurement and Reporting

Continuous improvement must be measured and reported. The measurement system will verify the progress of improvement efforts. When properly performed, a measuring and reporting system furnishes accurate, systematic and objective data that provides employees and customer representatives with a clear understanding of past performance. This system will also provide a data base that can be used to facilitate improvements.



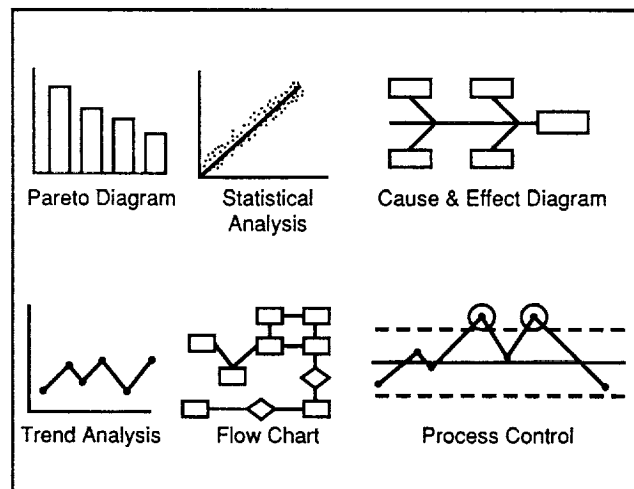
## 6.0 Training/Education

To succeed, the ASRM work force from top management to new employees must understand our approach for continuous improvement. Management will support and attend training/education efforts. The main arena for education in the use of TQM tools and Continuous Improvement is in the team approach.

## 7.0 Tools

Some of the continuous improvement and TQM tools which will be utilized are:

- Brainstorming
- Flow charts
- Histogram
- Cause and effect diagrams
- Quality planning spreadsheets
- Designed experiment (Taguchi)
- Statistical analysis/process control
- Measurement system analysis
- Pareto analysis
- Plan-do-check-act
- And others



## 8.0 Recognition

Recognition of significant contributions by individuals or teams will generally take place through public acknowledgement of their work in the presence of their peers. This recognition is the responsibility of the functional organization.

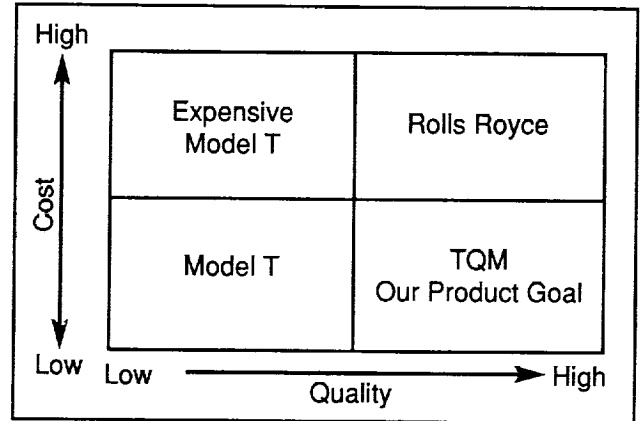
Team recognition will be a priority of the Executive Council.

Recognition will consist of, but will not be limited to the following options:

1. Award of Achievement
2. Personal letter of commendation
3. Verbal commendation in group setting
4. One-on-one handshake and thank-you
5. Promotions, bonuses, and merit increases
6. Luncheons to honor exemplary individual or team performances
7. Peer-initiated awards
8. Pay for performance

## 9.0 Summary

Our objective is to achieve a level of understanding whereby all employees embrace the approach of TQM and Continuous Improvement. We strive to achieve customer satisfaction by meeting the customer's needs in providing a quality product on time and within budget. ■



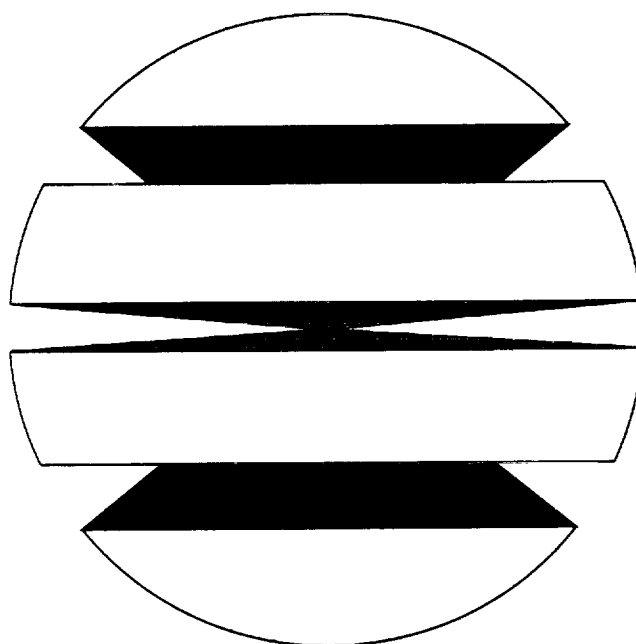






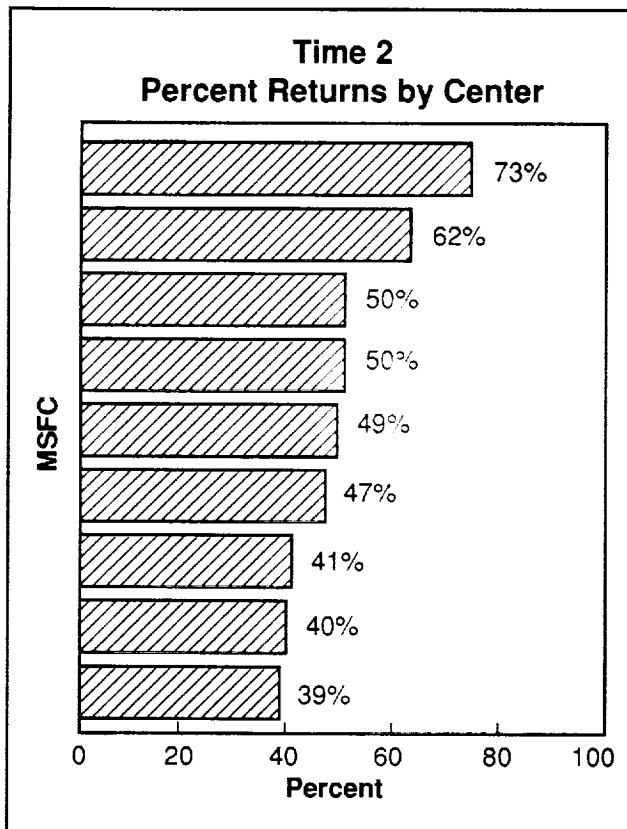


## CULTURE REPORT



**MARSHALL SPACE FLIGHT CENTER  
1989**

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201 Wolf's Lane  
Pelham, NY 10803  
Tel: (914) 736-0080



The GOOD news is you work for NASA

The BETTER news is you work for MSFC

The BEST news is "It's Getting Even BETTER!"

## NASA Culture Study

### Goal

- To understand the forces in the NASA culture that potentially promote or inhibit the organization's performance.

### What

A comprehensive look at what employees value, believe, and perceive to be true about:

- NASA as an overall agency and what is important in the respective centers.
- How they go about doing business i.e., "The way we do things around here"

### When

- NASA culture survey administered
  - Time 1: December 1986
  - Time 2: March-June 1989

### Who

- Time 1:
  - 3,008 NASA responses
  - Overall return rate: >70 percent
- Time 2:
  - 9,637 NASA responses
  - Overall return rate: >47 percent (Time 2 - sent 20,088 surveys)

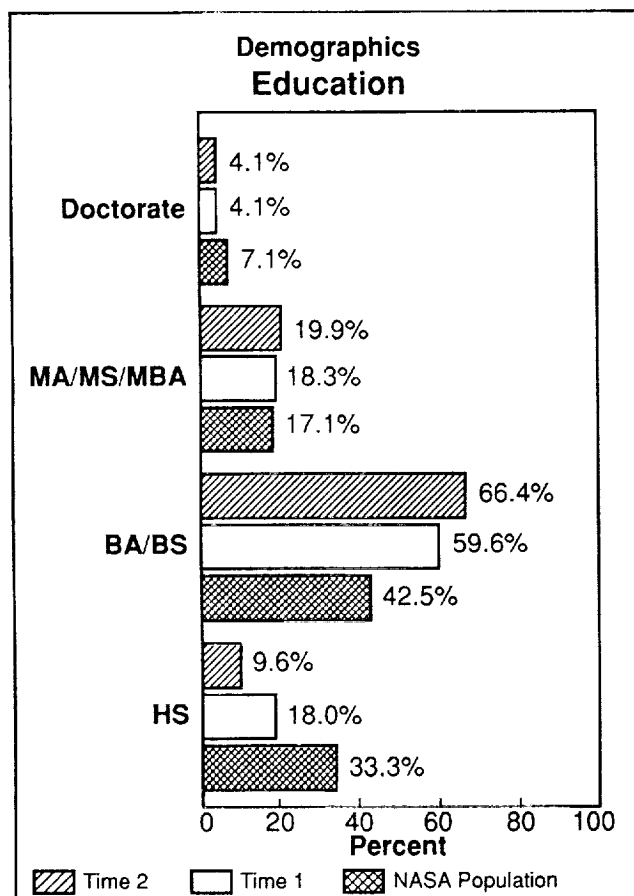
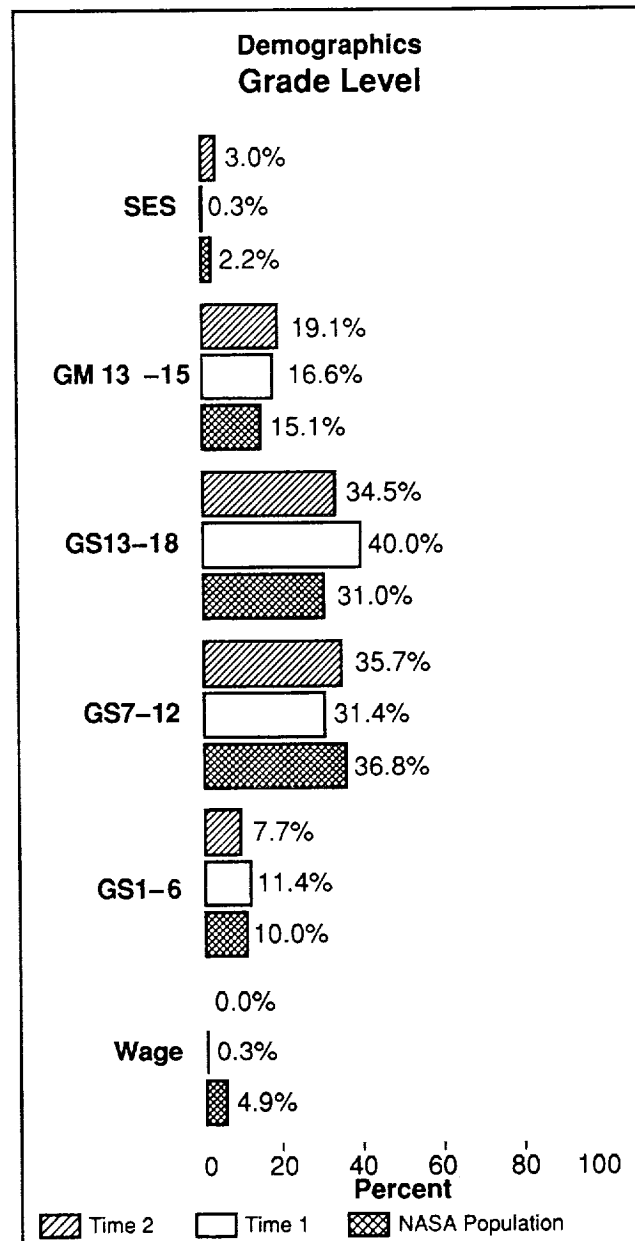
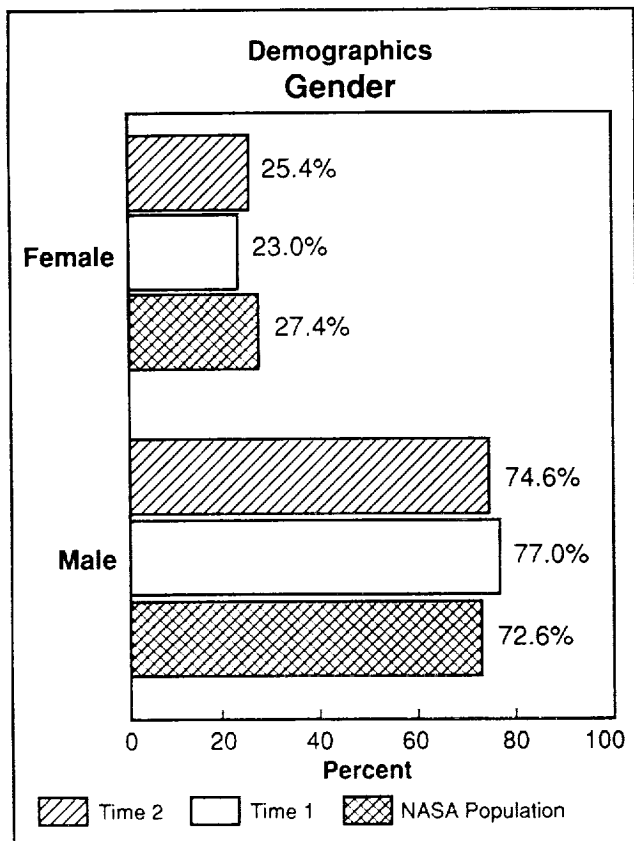
### Time 2 Center Return Rate

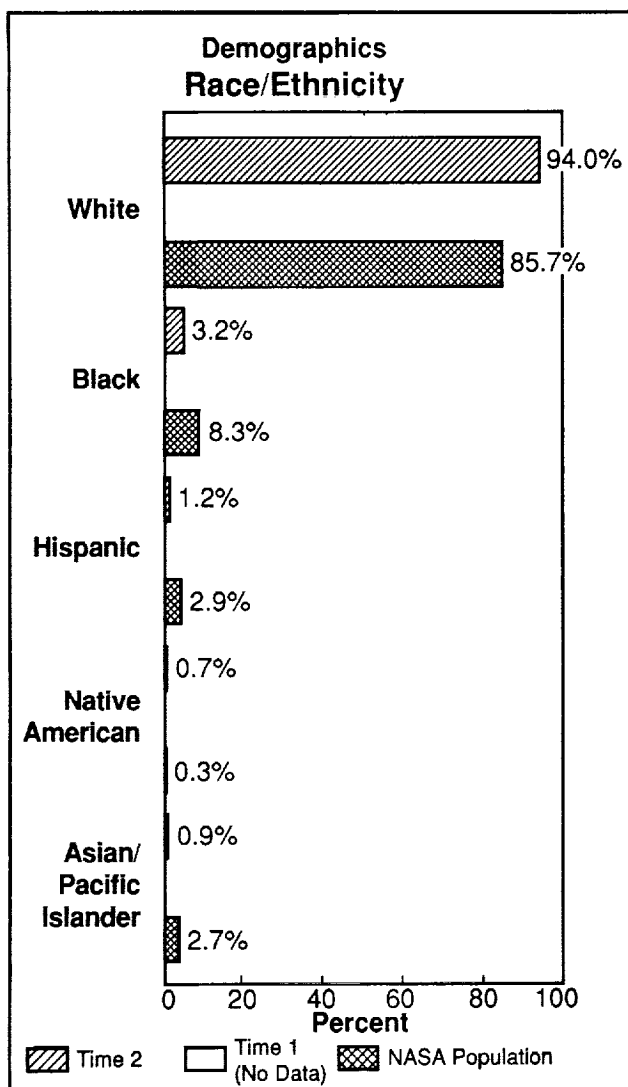
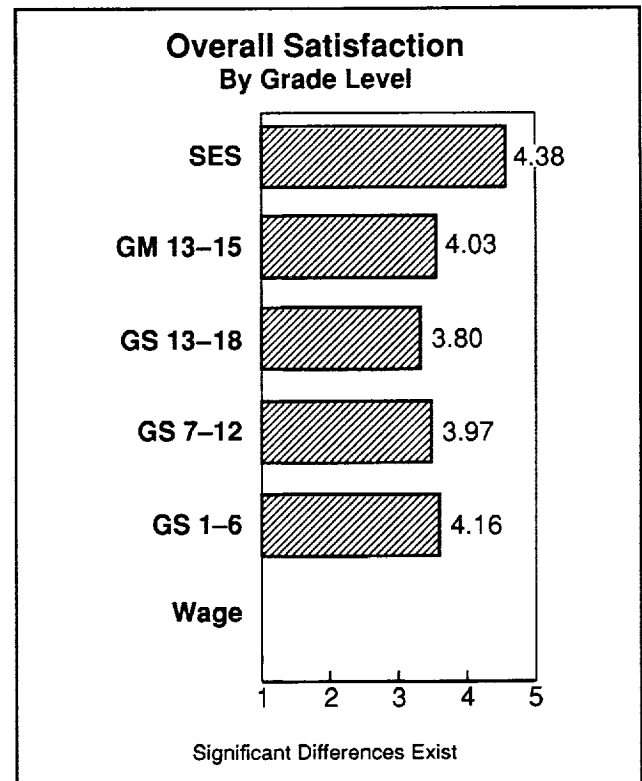
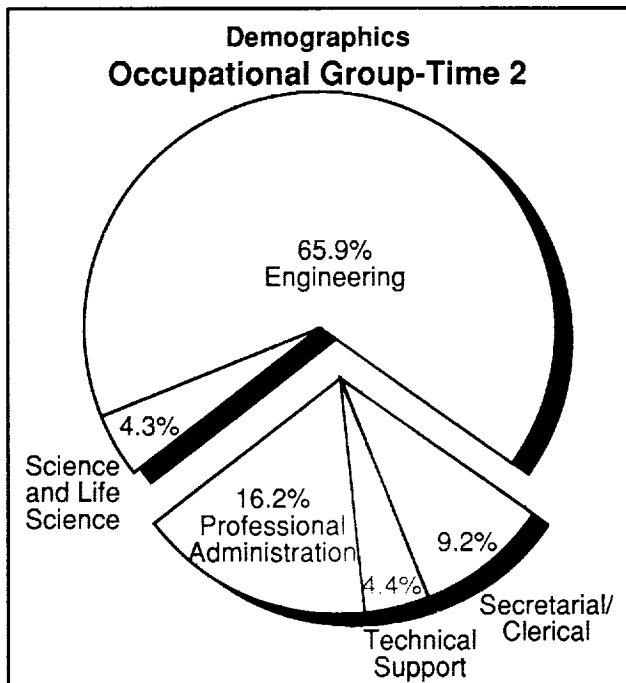
Date	Center	Surveys Sent	Usable Returns	Percent Returned
May	MSFC	3,340	1,671	50

Agency return rate: 47 percent

### Demographics

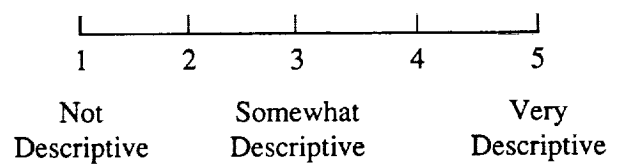
	Time 2	Time 1	NASA 1989 Population
Average Age	42.2	44.3	43.3
Avg. Yrs. NASA	14.9	17.6	14.3



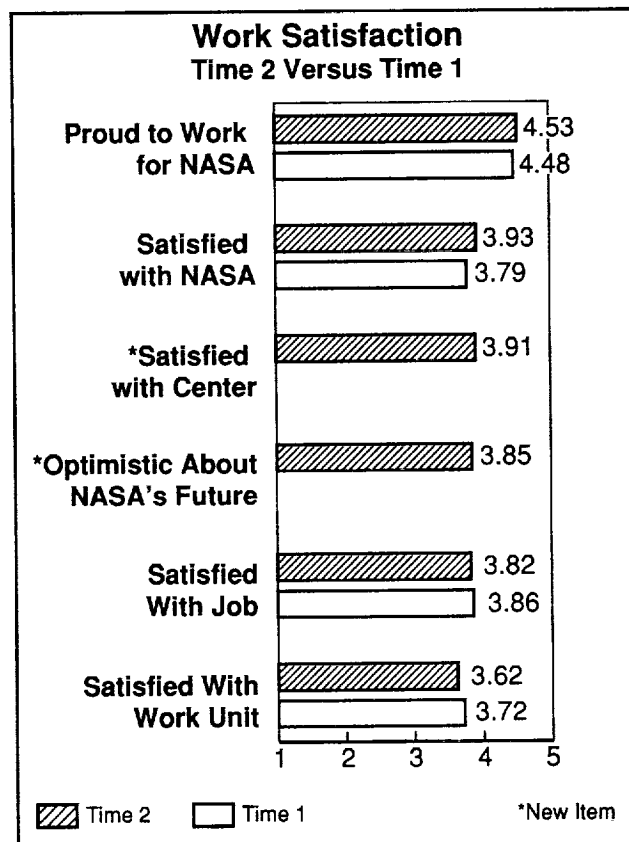
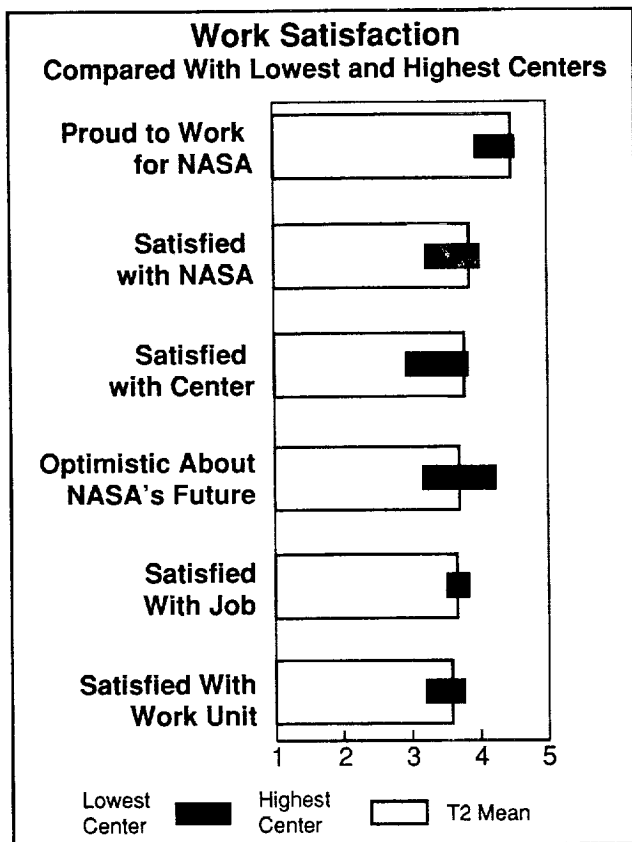


## The Culture Study

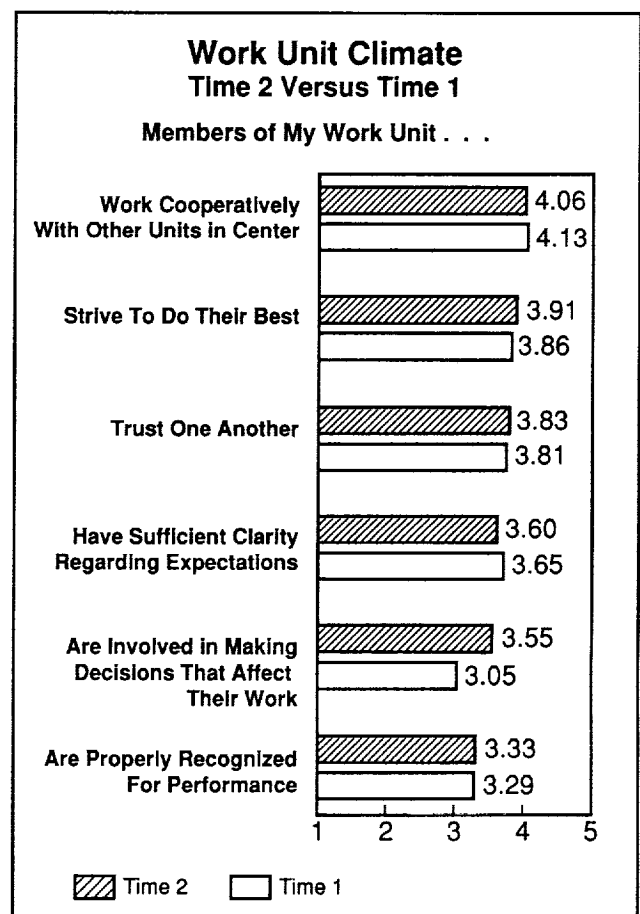
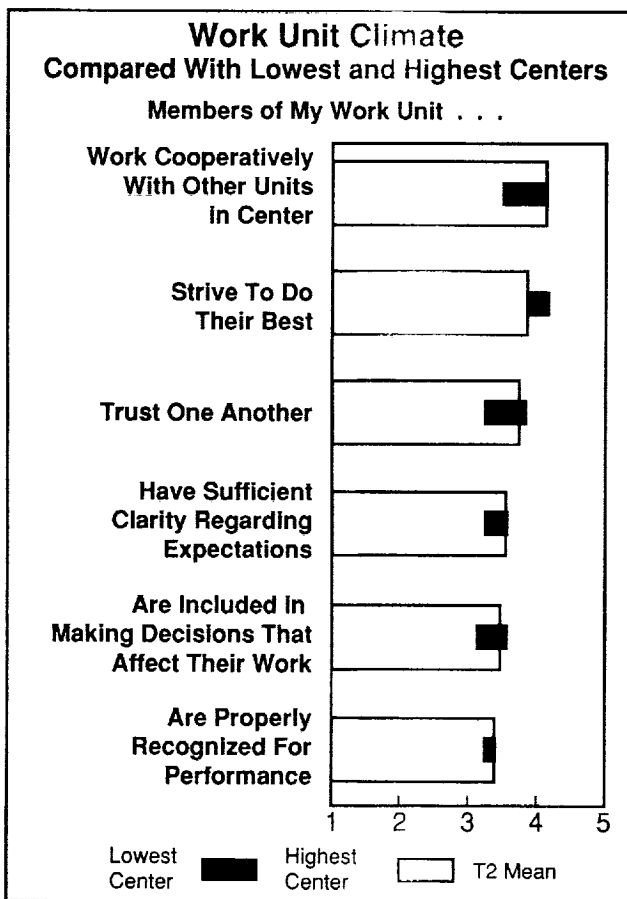
Each item in the culture questionnaire was rated using the 5-point scale below:



## Culture Findings Section A: Work Satisfaction



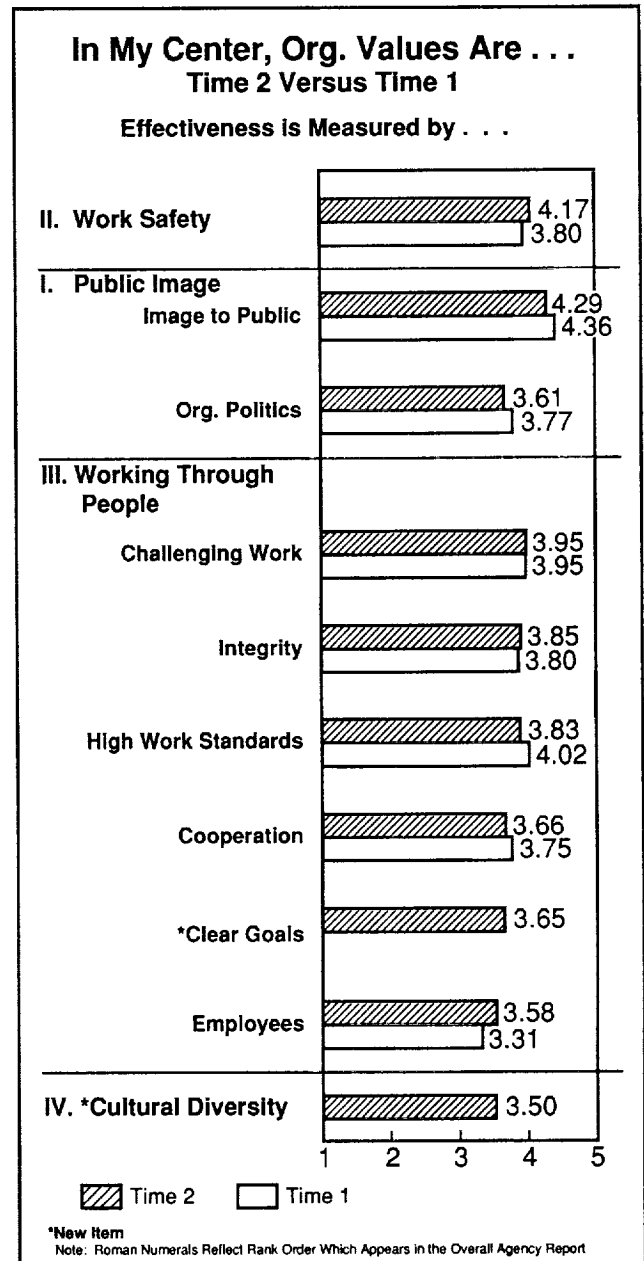
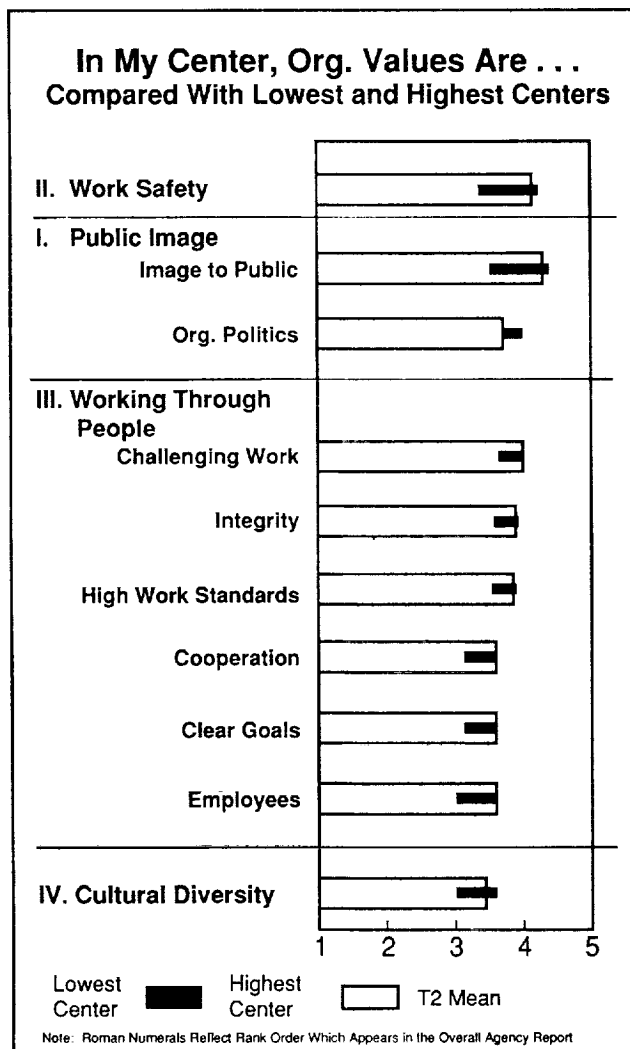
## Culture Findings Section B: Work Unit Climate

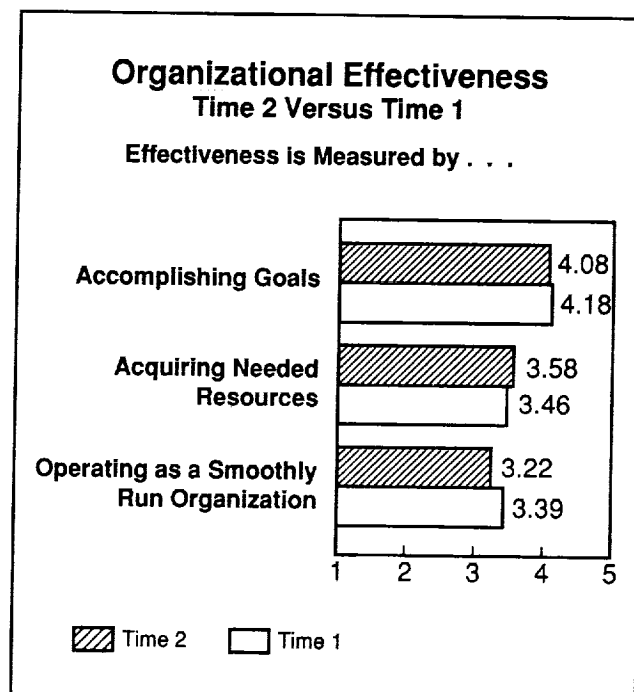
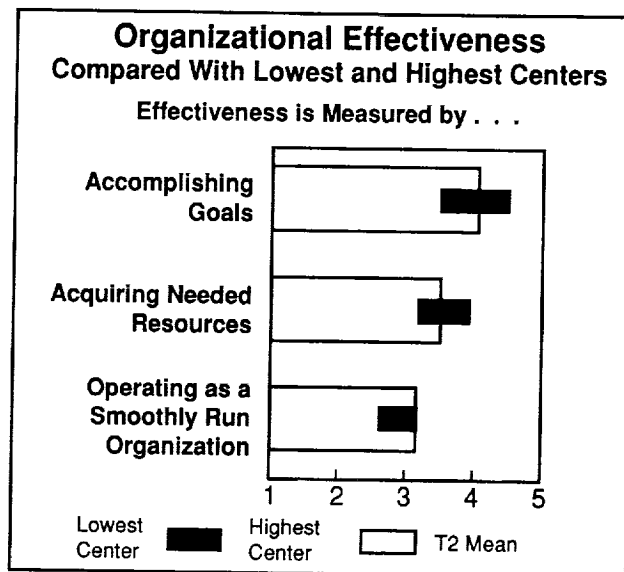
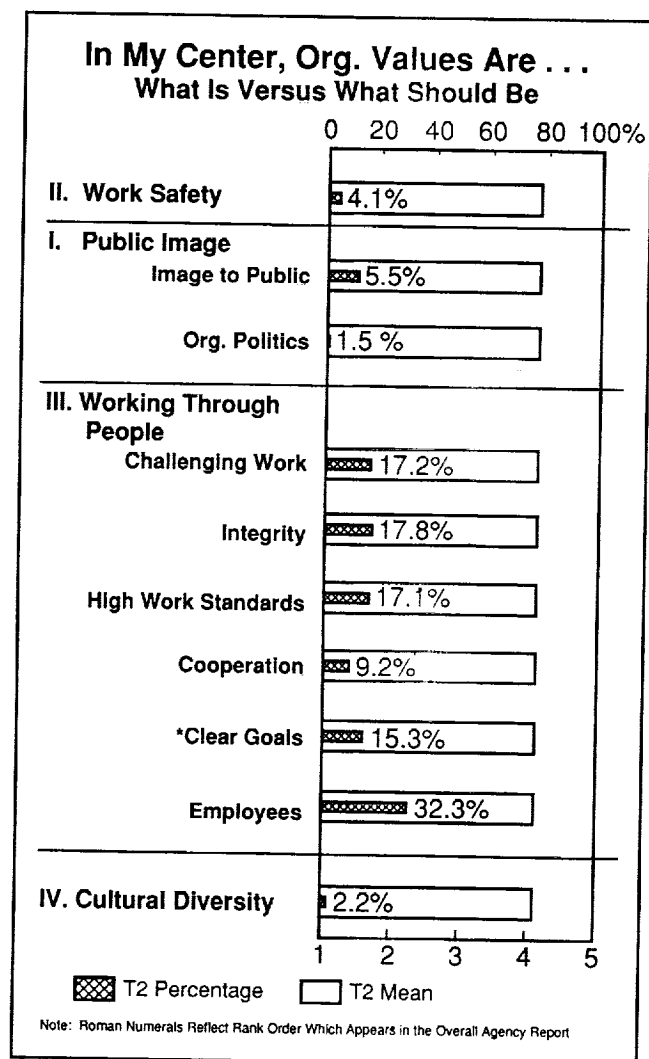




## Center Culture

- Organizational values
- Organizational effectiveness
- Loyalty
- Support
- Innovation
- Trust
- Adaptability
- Problem Solving
- Communications
- Rewards
- Power sharing
- Career development
- Decision making
- Senior management emphasis









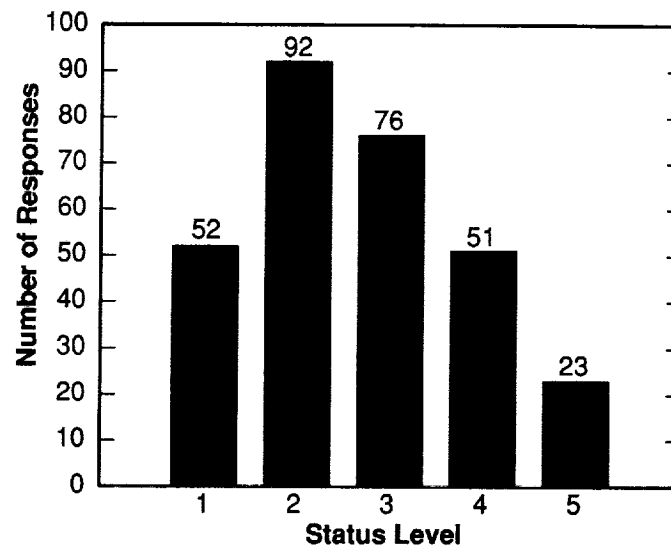
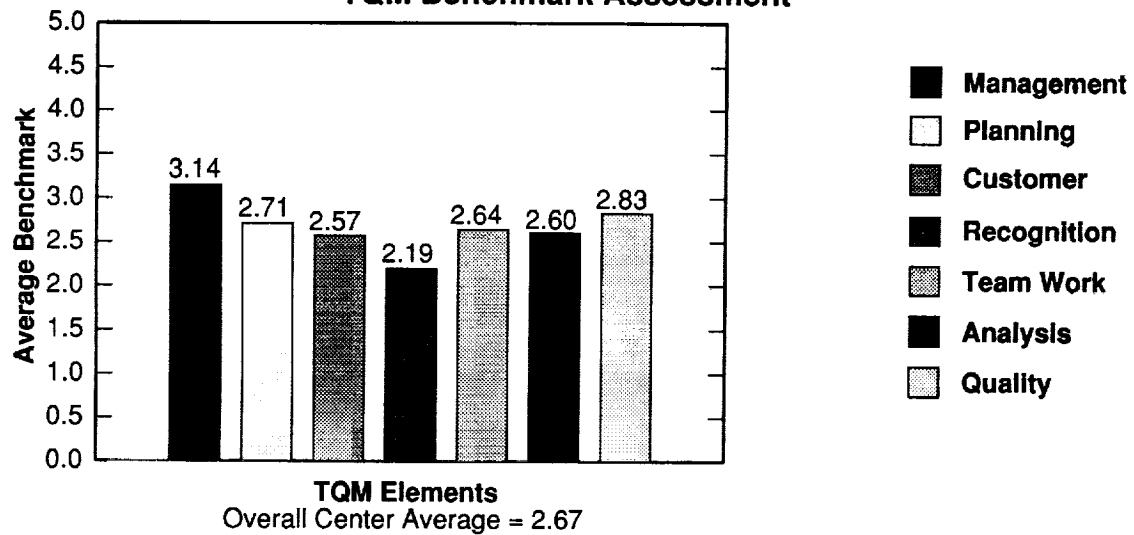
# TQM Benchmark

TQM Element		A	B	C	D	E	F	G
Status Level		Top Management Leadership and Support	Strategic Planning	Focus on the Customer and Partners	Employee Training and Recognition	Employee Empowerment and Teamwork	Continuous Improvement Measurement and Analysis	Continuous Quality Assurance Activity
Desired Direction ↑	5	Senior Managers personally and visibly involved. TQ culture permeates organization. Active removal of barriers.	Planning effort is integrated, cross function and centerwide. Action plans developed at all levels. Customer needs a primary planning tool.	Innovative methods for obtaining customer feedback. Partnerships established to support continuous improvement.	All trained in and using TQ. Innovative incentive systems. Comprehensive systematic training.	Participative management the norm. Short chain-of-command. Employee enthusiasm apparent.	Continuous improvement progress tracked in all areas. Process flow-time and costs down in all areas.	Exceptional results from continual assessment and benchmarking of all products, services.
	4	Senior Managers participate in key activities. Departments cooperate. Managers held accountable for quality.	Action plans at most levels. Customer needs a significant factor in planning. Many planning participants from across the organization.	Effective feedback system for obtaining customer information and improving services.	Nearly all using TQ methods. Team achievement widely celebrated.	Widespread participative management and downward delegation. Team ownership of process improvement.	Continuous improvement progress tracked in most areas. Process flow-time and costs down in key areas.	Positive performance trends from systematic assessment benchmarking for comparison.
	3	Senior Managers fully support TQ. Adequate resources invented some cross functional implementation.	Action plans developed in key mission areas. Broad participation. Customer needs influence planning.	Customer feedback regularly solicited for management action. Supplier quality monitored.	Almost all trained in TQ. Recognition of teams for continuous improvement efforts. Significant training resources.	Participative management style. Trust growing between managers and employees.	Quality data often used to track progress and identify problems/ solutions. Some improvements noted.	Assessment of all products, services for outside customers and most for internal customers.
	2	Many managers support TQ. Numerous improvement projects underway. Cross functional implementation encouraged.	Specific goals established. Customer needs considered in planning. Some participation from across the organization.	Customer feedback solicited on an ad hoc basis. Supplier performance not systematically backed.	Managers and some employees trained in TQ. Some rewards for quality improvements. Some training resources.	Many managers support teams. Many employees on teams. More cross functional cooperation.	Some units collect and analyze quality data to prevent errors. Beginning process and product improvement.	Most products, services for outside customers reviewed. Positive results.
	1	Some managers support TQ. Some resources allocated, but few projects underway.	General goals established. Customer needs not central to goal setting. Not an integrated effort.	Customer complaints primary method of feedback and not systematically used to improve processes.	Minimal training resources, training at TQ awareness level. Mostly managers. Occasional recognition given.	Few quality improvement teams, traditional management style. Little cross functional cooperation.	Quality control by inspection or review. Quality data source. Feedback system in planning stage.	Some products, services reviewed to meet customer needs.
		Degree of Line Involvement ↑						

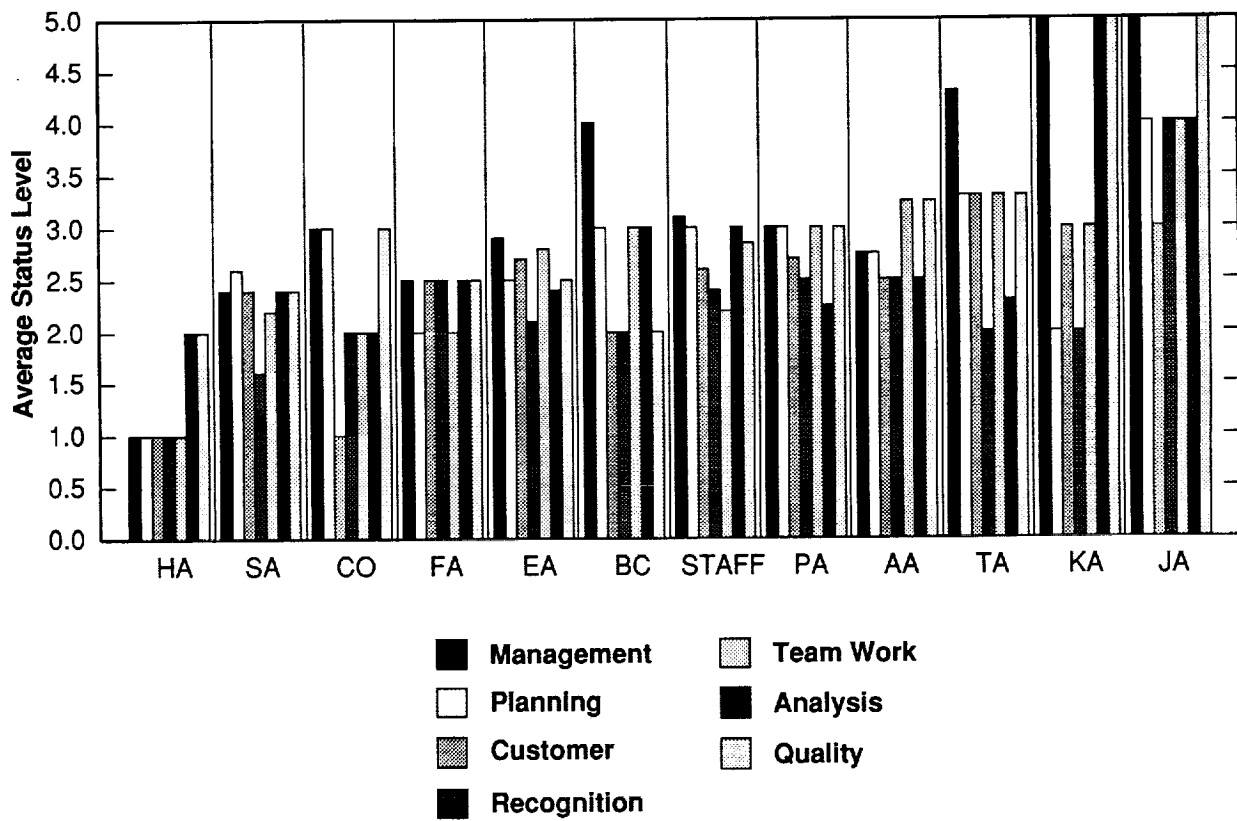
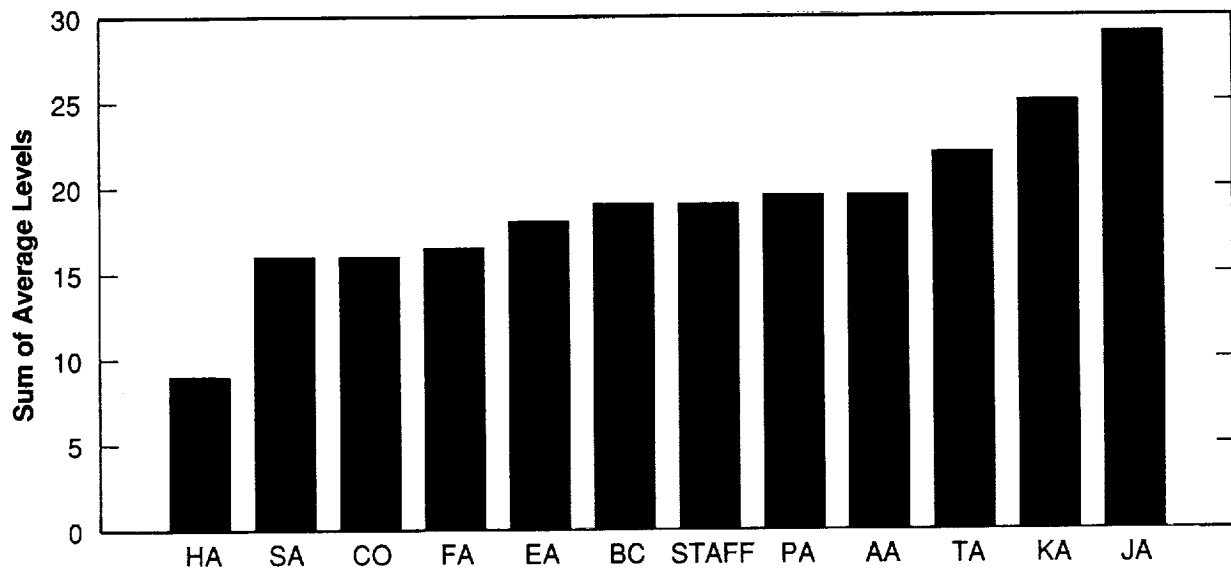
## TQM Self Assessment

TQM Element/ Status Level	Management Leadership and Support	Strategic Planning	Focus on the Customers & Partners	Employee Training & Recognition	Employee Empowerment & Teamwork	Continuous Improvement Measurement & Analysis	Continuous Quality Assurance Activity
5	10	2	1	2	3	3	3
4	7	9	10	2	9	5	10
3	6	13	8	10	12	14	13
2	12	11	16	19	8	17	10
1	7	7	7	9	10	3	6
MSFC Mean	3.02	2.71	2.57	2.26	2.69	2.71	2.86
Agency Mean	2.44	2.46	2.59	2.08	2.43	2.32	2.37

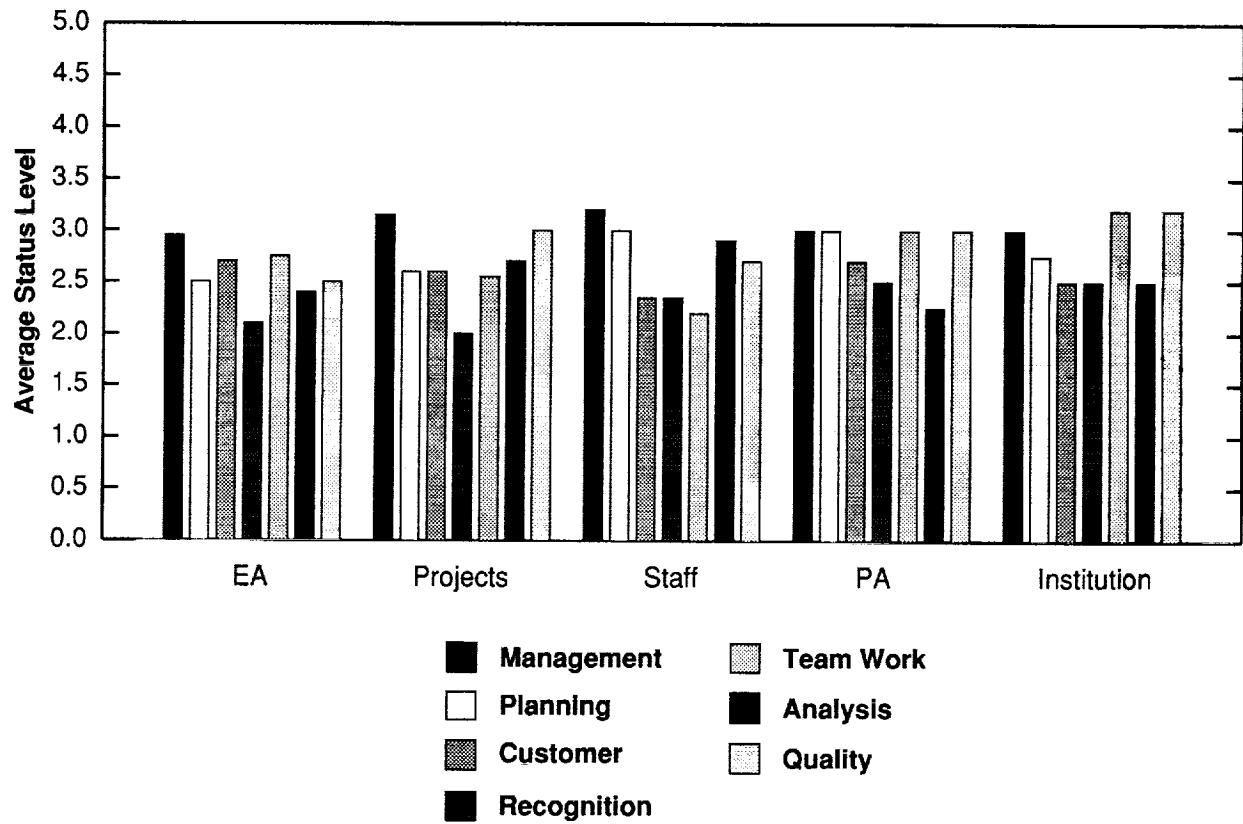
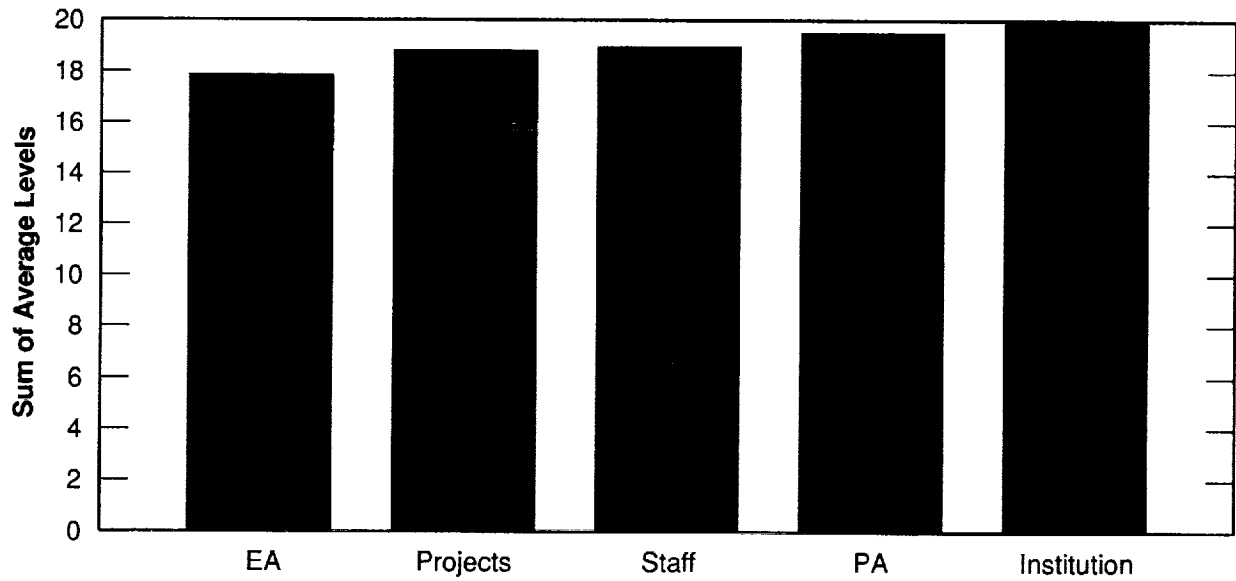
### TQM Benchmark Assessment



### TQM Status Level by Organization

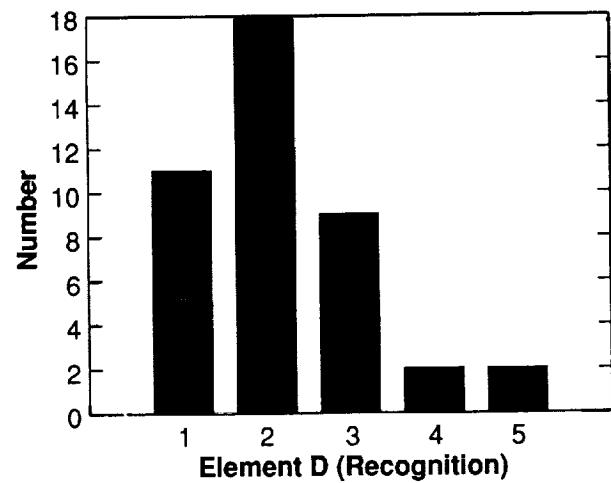
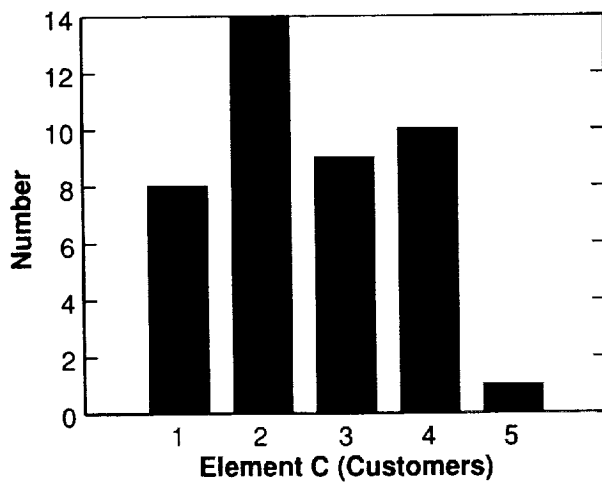
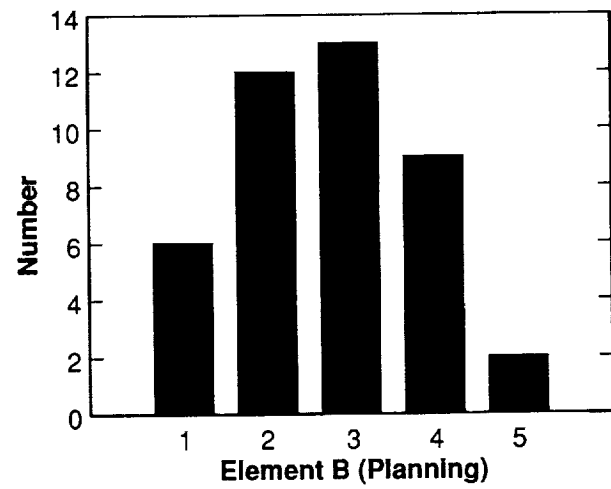
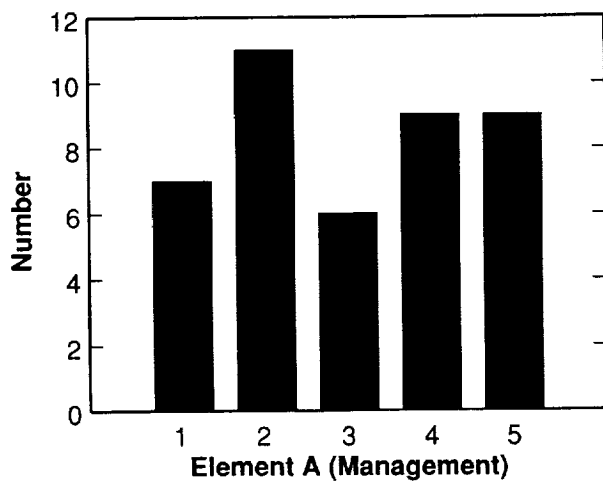
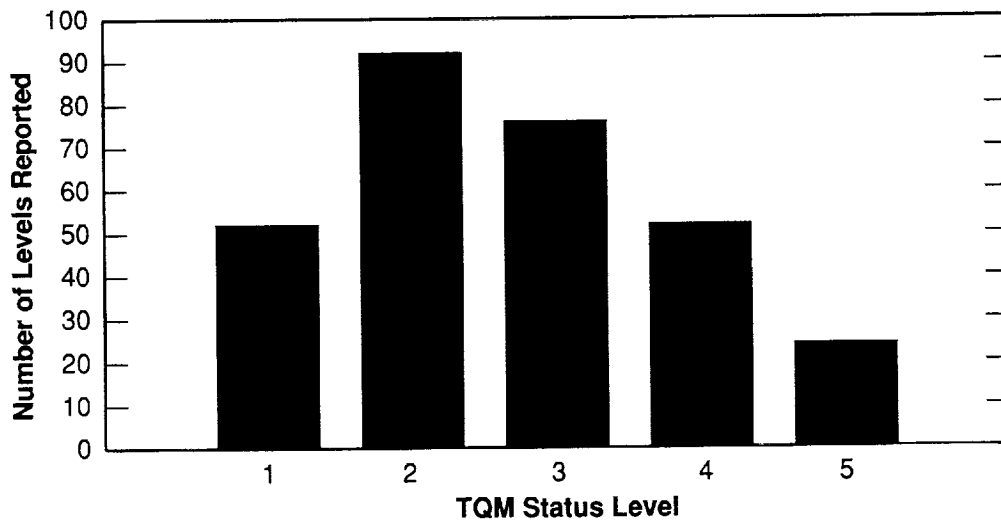


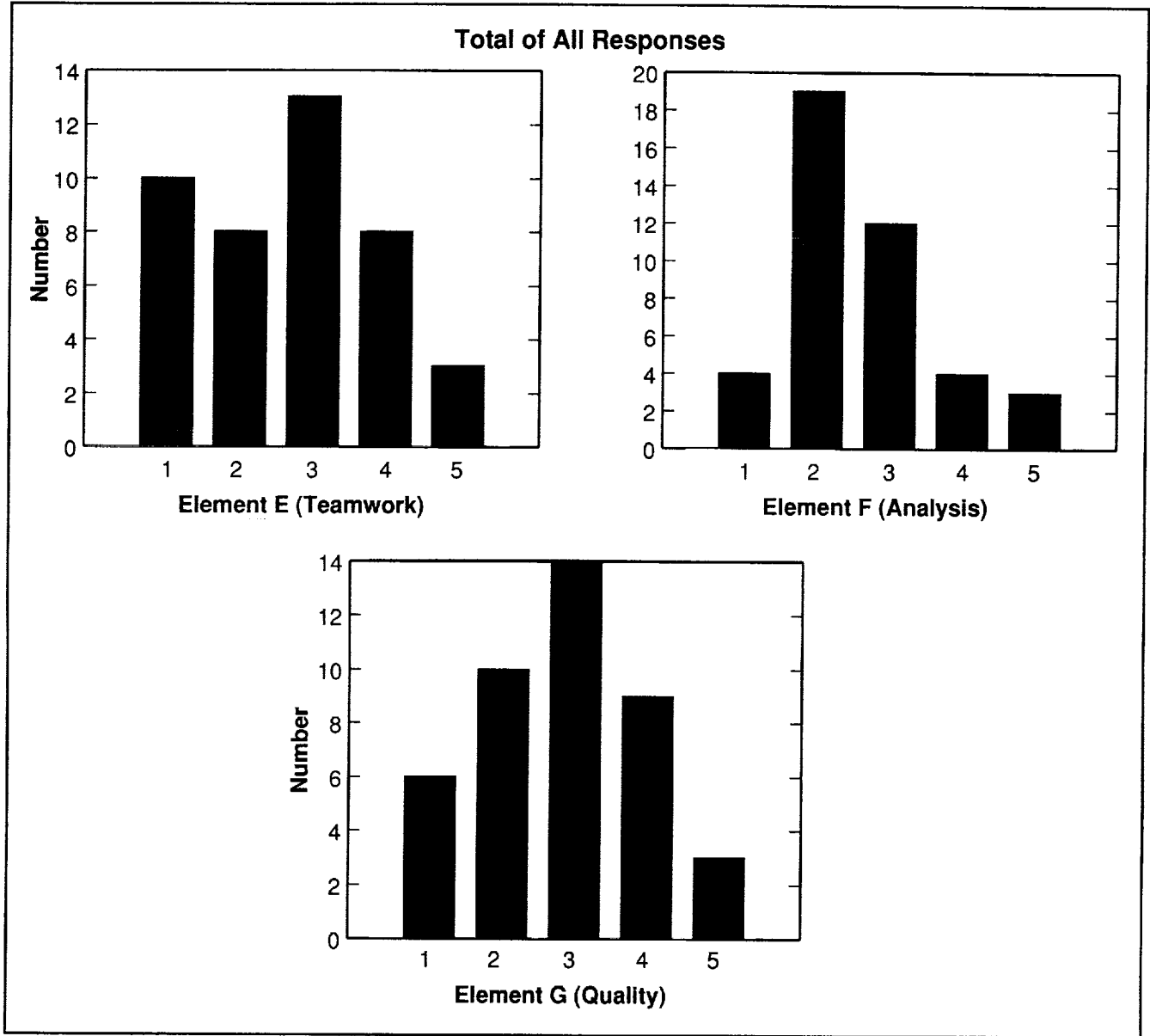
### TQM Status Level by Organization





**Total of All Responses**









# Communication Study Team Report to Center Council

December 20, 1990

## Study Objective

The objective of the Communication Study Team was to examine problems or perceived problems in communication and explore ways to improve them. Two areas of communication were involved:

- 1) External to MSFC
- 2) Within MSFC

We are to explore innovative ideas/ways to communicate more effectively.

Ask why we are doing things this way and is there a better way.

## Communications Study Team Members

Robert Champion	PD13, Chairman
Pegi Dunnigan	CN44
Renee Ingersoll	EL43
Bob Keasling	AI32
Bill Simpson	KA30
Jeff Spencer	CQ22
Angela Stewart	EO24

## Agenda

### Introduction

- Schedule
- Background and observations

### Communication External to MSFC

- Education efforts
- Public image
- Intercenter competition

### Communication Within MSFC

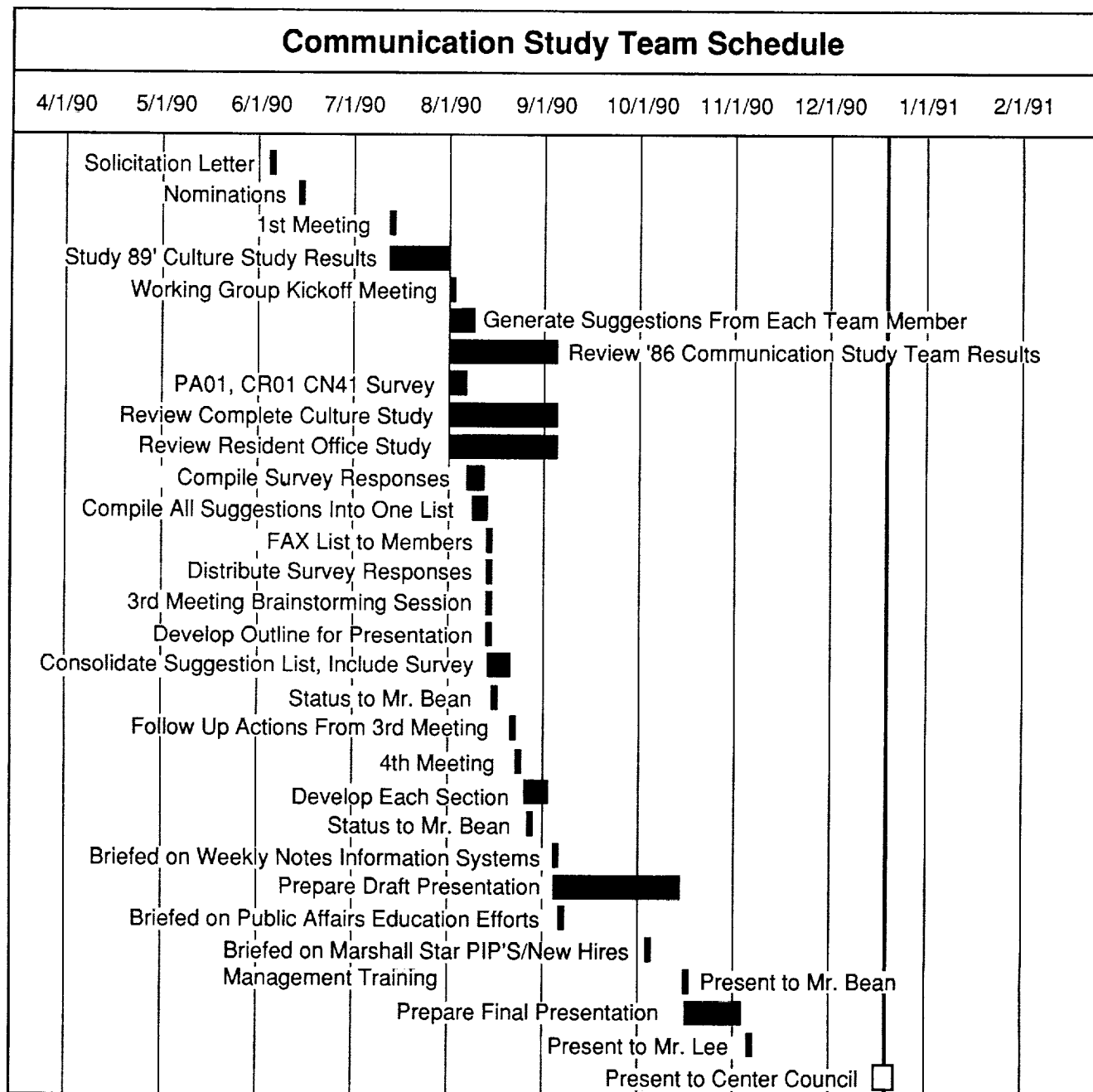
- Electronic mail
- Employee updates
- New hires
- Meetings/weekly notes

- Management<—> employees
  - Openness
  - Communication skills
- Other/general information

Recommendations/follow-on

## Communication Study Background

- Areas identified as needing further attention in 1989 culture study:
  - Career development
  - Decision making
  - Rewards
  - Power sharing
  - Communications
- Communication study team set up by Mr. Bean
  - Center-wide representation
  - Employees with less than 5 years at MSFC
  - 7-member team
- Past communication studies and surveys
  - 1989 and 1986 culture study
  - 1986 communication study team chaired by Mr. Odom
  - “TNT-Teams and Technology Dissertation” by Jackie Kutsko
- 1,500 new employees have been hired over the last 4 years
- Over the past 15–20 years the emphasis on new employee orientation has dropped off because new employee hiring has only recently picked up.



## Cultural Study Observations

Communications spans almost all aspects of NASA culture. The questions from the 1989 survey show this.

### Decisions

- Decisions are based on open discussion and debate of facts. Once a decision is made, management communicates the results and rationale to employees

### Rewards

- The performance appraisal system provides a useful forum for discussion of work performance

- People orientation is an important criterion for the advancement of managers

### Loyalty

- MSFC is effective in orienting new employees

### Support

- There is a willingness to collaborate across organizational units within MSFC

### Trust

- Employees can say what is right without fear of reprimand from management

## **Power**

- We talk about teamwork and sharing, but people quietly hold on to their power and authority

## **Problem Solving**

- Issues can be discussed clearly and openly without having a negative impact on personal relationships

## **Organizational Functioning and Adaptability**

- Employees at MSFC have clear concepts of their own roles and how they relate to the roles of others

# **Communication External to MSFC**

## **With Public Media**

We must do a better job of promoting ourselves and the value of engineering and science to our nation.

- Encourage middle management to support employee public speaking
- Provide special recognition and incentives for involved employees
- Provide public speaking training to selected employees
- Increase emphasis to educate the work force on NASA school initiatives (Star, NASA updates)
- Increase resources to support for school initiatives (Spacemobile, Project LASER, etc.)

## **With Other Centers**

Unhealthy competition exists among NASA centers.

- Encourage the use to tele/videoconferencing more accessible
- Encourage temporary personnel assignments among centers
- Provide clearer definition of tasks among NASA center early in program

# **Communications Within MSFC**

## **Electronic Communications**

MSFC could more effectively use its computer resources.

- Commit to transition to a paperless system

- Provide transparent communication across existing systems (X.400 addressing)
- Make systems compatible
- Educate employees on existing capabilities

## **Employee Updates**

Viewing updates is difficult at times.

- Reserve conference rooms for employee updates
- Establish a standard time for employee updates
- Add monitors, as necessary (could be in branch chief's office)

## **New Hires**

The professional intern program needs to be standardized.

- Require PIP's to have 2–3 rotations of three months each
- Require meeting with new station to list duties and responsibilities
- Mandatory briefing by lab directors and organizations

## **Staff Meetings**

Need for more face-to-face communication.

- Have weekly branch meetings
- Have quarterly office/lab director meetings with all employees

## **Weekly Notes**

Purpose of weekly notes is misunderstood.

- Should not be mandatory (quota) or part of performance appraisal
- Use activity reports for performance items instead of weekly notes
- Distribute lab/office/center notes quickly, use electronic mail/bulletin boards

## **Management/Employee Openness**

Nobody likes to be “kept in the dark”.

- Conduct informal but scheduled walk-throughs by all levels of management to “break the ice” and promote team spirit

- Hold less information in confidence
- Publish user-friendly memos, explaining the promotion, award, and hiring processes and allocations
- Invite/encourage personnel to attend project office meetings
- Don't hoard information, keep it flowing

### **Management Communication Skills**

Some managers have poor people skills.

- Work on better team building skills
- Establish center emphasis on enhanced communication skills
- Include people skills in evaluation process for potential managers
- Include communications and human relations initially in training of pre-supervisors
- Include people skills in performance plans of all supervisors

## **Communications Within MSFC**

### **Other/General Information**

Employees need a better understanding of what goes on around MSFC.

- Use public address system to notify employees of significant events, especially those scheduled on short notice
- Bulletin boards need to be updated, revamped, and placed better
- Expand the Marshall Star or perhaps begin an employee newsletter
  - Include a paragraph once a month on what PD, S&E, or I&PS is doing
  - Monthly pictorial focus on a certain division/branch activity
  - Have an editorial section to accept comments and respond to questions
  - Include human interest stories
- Encourage lab/office newsletters—OK reproduction
- Re-look the purpose of the weekly bulletin

### **Team Building**

Team concept is often overridden by employee concept.

- Form teams on a proactive rather than a reactive level, include representatives from different areas
- Make management aware of the communication concern, instruct management to encourage involvement, solicit employee feedback on management performance
- Recognize nontechnical support contributions

## **Recommendations/Follow-On Activities**

- Recent MSFC achievements:
  - Daily Planet
  - Employee handbook
  - TQM seminars
  - Furlough warning
  - Supervisor handbook
  - CCTV used for picnic announcement
  - Career development handbook
  - Limited use of public address system

## **Recommendations**

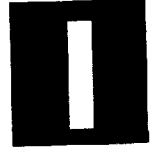
- Communications with public/media
  - Make education work more visible to public and employees
- Communications within NASA
  - Provide for more intercenter interchange, reduce conflicts
- Communications within MSFC
  - Make center priority/commitment to improving communications known
  - Make employee updates more effective
  - Train new employees more consistently
  - Improve use of staff/employee meetings
  - Improve team building and communication skills
  - Rethink the purpose of the Marshall Star
  - Encourage more use of electronic mail
- Select changes to implement
- Implementation options
  - Establish teams with senior management involvement to oversee and monitor progress
  - Perform within management structure
- Must have management commitment and direction at all levels



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## Appendix

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# Acquisition Enhancement Survey

L. Mullins and L. Zoller

The acquisition enhancement survey was initiated by the Center Director in April 1990, as part of the Total Quality Management (TQM) effort.

The survey findings and recommendations are contained herein.

## Issues

- The perception being that:
  - We can't "control" programs
  - We can't "get anything through procurement"
- Do we need to OVERHAUL the acquisition process
- Can the acquisition process be further streamlined?

## Notes

The acquisition enhancement survey study was undertaken with the participation of the Center organizations to establish an understanding of what the current processes entail, the origin of requirements, and if, or how, they might be modified to be more responsive to user needs and more successful in terms of Total Quality Management.

The findings and recommendations represent the collective input of many persons from all Center elements.

## Global Findings

Acquisition policies, procedures, and system are fundamentally SOUND.

Acquisition enhancement efforts are being implemented.

- Automated Procurement Request System (APRS)
- Off-the-shelf software procurements (<\$1K)
- Restock of supplies

- Off-the-shelf training package procurement
- Streamlined SEB/C process by Headquarters
- Standardization of documentation
- FIP (ADPE) procurement through BCSS contract

Achieved programmatic results are disappointing.

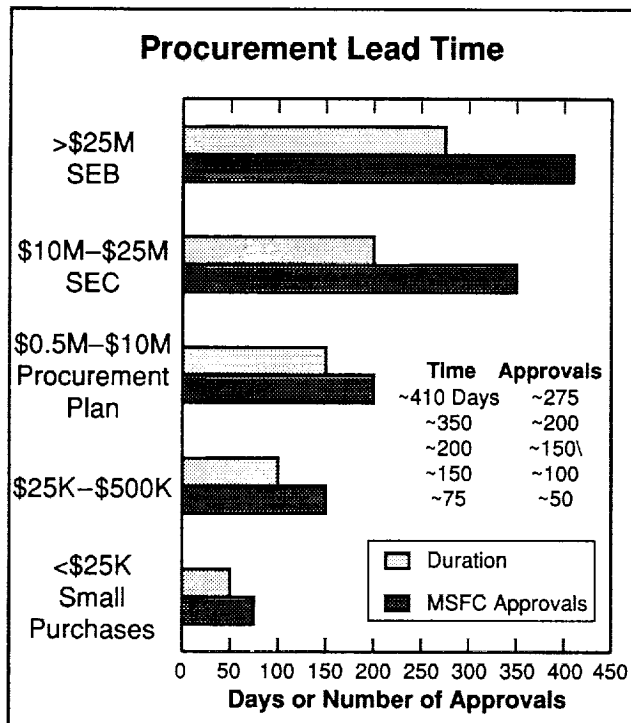
Attention is needed on fundamentals, as well as opportunities for process streaming.

## Notes

While the procurement process is highly successful in terms of accomplishing and sustaining contractor selections, the attendant consumption of time and resources, and subsequent cost growth, schedule slippage, and untimely—sometimes, erroneous—deliveries signal undesirable programmatic results. Identified programmatic problems and sluggishness in the acquisition process are due more to **laxity** in the application of established management principles and **excesses** approvals and conservatism than to any fundamental fault of the process. There is generally sound rationale and logic for the **steps** in the acquisition process, although several **post**-selection steps (e.g., technical evaluation, pricing, and pre-negotiation objectives) could be eliminated through incorporation in SEC/SEB documentation. Achievement of TQM lies in the process implementation through delegation of responsibility and authority, communication and training, standardization, and, in certain areas, methodology and role changes.

## Z's Therorems

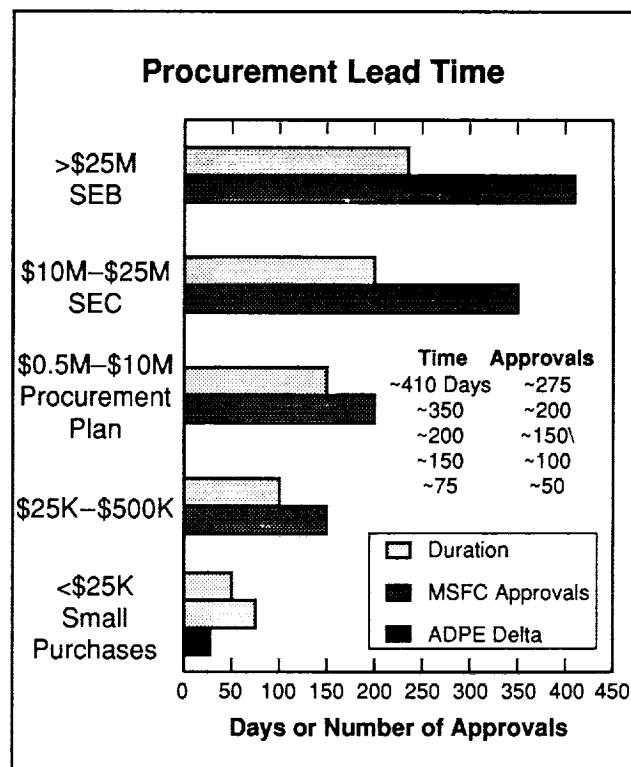
- Programmatic growth is a function of Avagadro's number.
- The "big view" of SE&I is myopic.
- The buck may stop with Harry Truman, but the project manager will cash it in.
- The number of reviews is measured in centipoise.
- ADPE items tend to be obsolete before receipt.
- The cost of small purchases is expended before award.



#### Notes

The process lead time is proportional to the number of MSFC reviews and approvals on each procurement; thus, the potential for streamlining and reducing lead time is related to delegation of authority and responsibility:

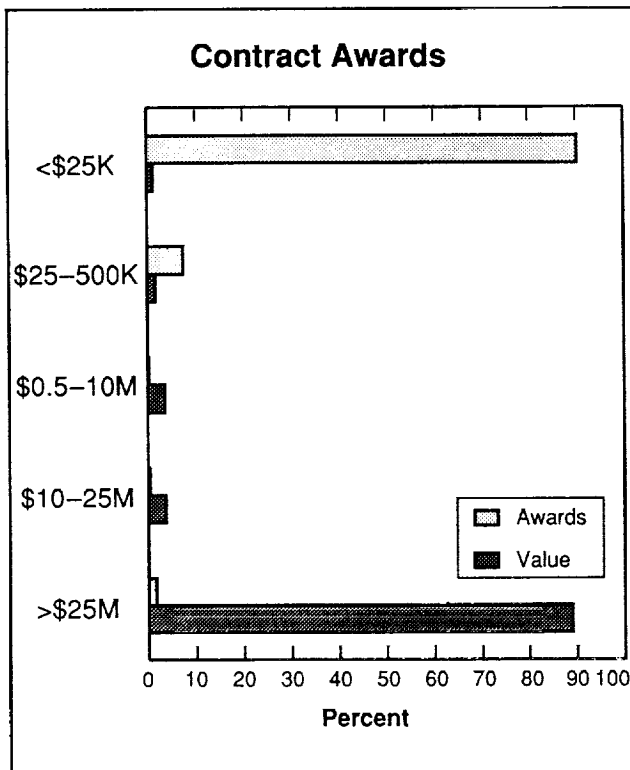
	Sealed Bid	SEC/C	SEB/C
Major system contract			≈275
Mission contract		≈150	≈200
Service contract		≈150	≈200
AE contract		≈75	
Construction contract	≈100		
ADPE procurement	≈175	≈200	
Goods procurement	≈100	≈125	



#### Notes

Statutory and policy times stipulations, together with maximum compression of all other events, account for about one half of the experienced procurement lead time:

	Minimum Elapsed Time			
	SEB	SEC	General	Small Pur.
Regulation	80 days	65 d	51 d	—
NASA policy	61	24	—	—
MSFC policy	14	9	—	—
Evaluation (initial and BAFO)	40	40	4	1
Other	27 222 d	16 154 d	15 70 d	31 32 d
Historical	≈410 d	≈350 d	≈150 d	≈75–100 d



### Notes

While major procurements get the most visibility, the preponderance of annual procurements are small purchases which consume extensive effort:

	Awards		Value	
Small purchases (<\$25 K)	≈4,900	≈91%	\$30 M	≈1%
General contracts (\$25-\$500 K)	≈400	≈8%	\$46 M	≈2%
Contracts (\$500 k-\$10 M)	≈40	≈8%	\$85 M	≈4%
Typical SEC actions (\$10-\$25 M)	≈8	≈0.2%	\$95 M	≈4%
Typical SEB actions (>\$25 M)	≈9 ≈5,357	≈0.2%	\$1,876 M \$2,132 M	≈89%

Furthermore, there is a high volume of change traffic to existent contracts:

Changes orders	≈524	\$2,249 M
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## Acquisition Survey

- Procurement of goods
- FIP (ADPE) procurements
- Facility contracts
- Service contracts
- Mission contracts
- Major systems acquisitions

### Notes

Step-by-step flow charts, starting with procurement requirements initiation through contract award, were developed and analyses were done for the following spectrum of procurement types:

- Procurement of goods—frequent use of small purchase practices.
- Federal Information Processing (FIP) procurements—extensive external constrained major source of user frustration (formerly ADPE)
- Facility contracts—formal process with high congressional visibility (AE or sealed bid procurements).
- Service contracts—specialized negotiated contracts with some unique requirements
- Mission contracts—wide range of negotiated contracts (typical user technical evaluation or SEC process).
- Major systems acquisition—endemic programmatic growth and high visibility (SEB process).

## Procurement of Goods and ADPE

- Process takes too long and consumes the time of too many people.
- FIPS (ADPE) constraints are, or will be, crippling.
- Data deficiencies and overly restrictive requirements cause delays.
- Users are frustrated by lack of status reports, and, sometimes, receipt of wrong items.

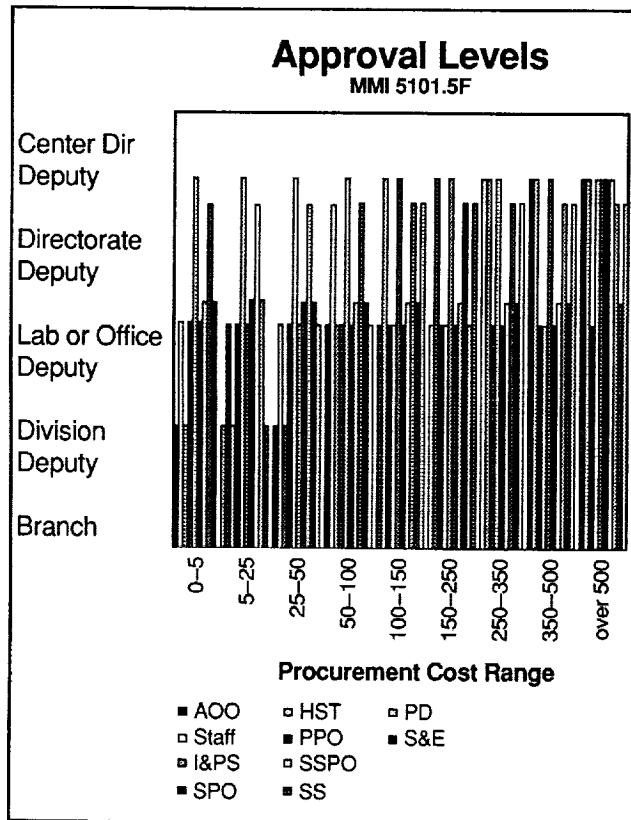
### Notes

The more familiar term, Automatic Data Processing Equipment (ADPE), addressed here, is now embraced

within the broader term Federal Information Processing (FIP) resources.

Typical procurement approval cycle time to contract award:

Small Purchases	Request	Procurement	Total
Goods	≈30 days	≈40 days	≈70 days
FIP (ADPE)	≈60 days	≈40 days	≈100 days
<b>Other (&gt;\$25 k)</b>			
Goods	≈40 days	≈90 days	≈130 days
FIP (ADPE)	≈100 days	≈90 days	≈190 days



## Notes

The "F" revision of MMI 5101.5 is a significant step in delegation of authority and responsibility, but disparities exist in the organizational approval levels for procurement requests (including differences within AOO and I&PS between Forms 55 and 404). Delegation of approval authority and responsibility to the lowest practical level is in keeping with TQM, and will facilitate APRS implementation.

The average number of individuals in a procurement request of <\$25 k (extracted from APRS) is:

S&E	7
CN (catalog screening)	1.5
AI/BCSS (FIPs only)	6
BF (funds authorization)	1
AP ( PROMIS log in)	2
	<hr/> 17.5

Naturally, the number increased with procurement value.

## Procurement of Goods and ADPE Potential Enhancements

### General (non-SEB/C)

- Minimize approvals and fully implement APRS. Phase out S&E Form 424.
- Delegate most "special approvals" to Property Management Division (MMI 5105.5F).
- Fully staff procurement office or contract small purchases (<\$25 k) services.
- Maximize use of indefinite quantity and GSA schedule buys, and credit cards.

## Notes

Procurement streamlining and APRS will be effective ONLY if the approvals are minimized. MMI 5101.5F should be revised to further delegate responsibility and authority, to make approvals the same for Forms 55 and 404, and to assign the preponderance to "special approvals" (attachment C) to Property Management Division. For example:

- ADPE and telecommunications equipment (items #1, 4, 8 k, and 9c)—A101
- Safety or security equipment (item #3)—CS01 or CN51
- Consultants (items #8b)—DA01
- Exhibits (item #8e)—CA01
- Most, if not all, others—CN41 (provide adequate guidelines and staffing)

APRS updates and full implementation should be expedited. S&E Form 424 would be obviated for procurement by APRS, and could phased out.

Some small purchases are made through institutional contracts; contracting for services for the remainder of small purchases would relieve the procurement office for more critical and challenging work (91 percent of all contract awards ate <\$25k), and should be given serious consideration.

Significant efficiencies would result from buyers, and, possibly, Directorate/Office Administrative Officials using credit cards for small (<\$1k), local non-competitive purchases (an APRS sample shows 50 percent of small purchases were <\$1k).

## Procurement of Goods and ADPE Potential Enhancements (continued)

### General (non-SEB/C)

- Provide center-wide procurement training and guidance materials (NET)
- Consolidate tracking and status of procurements through a single system.
- Confirm requirements and responses with initiators.

### Notes

Many of the issues identified through the survey indicate the need to center-wide training relative to the procurement process, and end-to-end tracking and status:

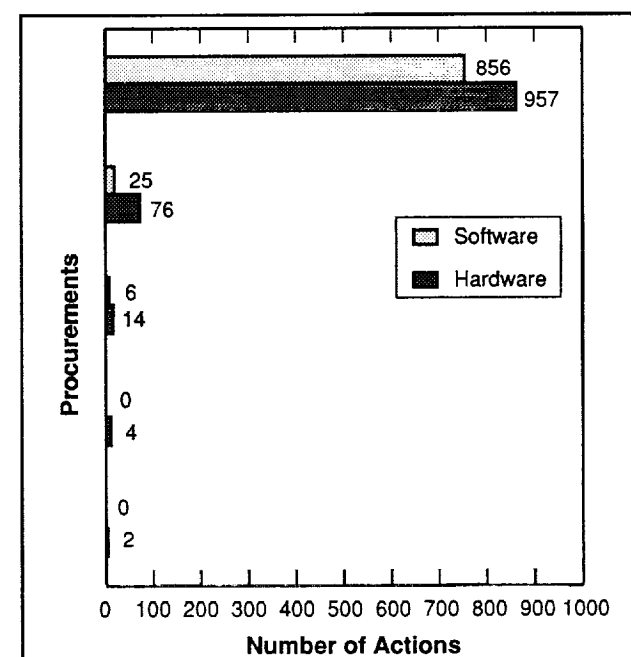
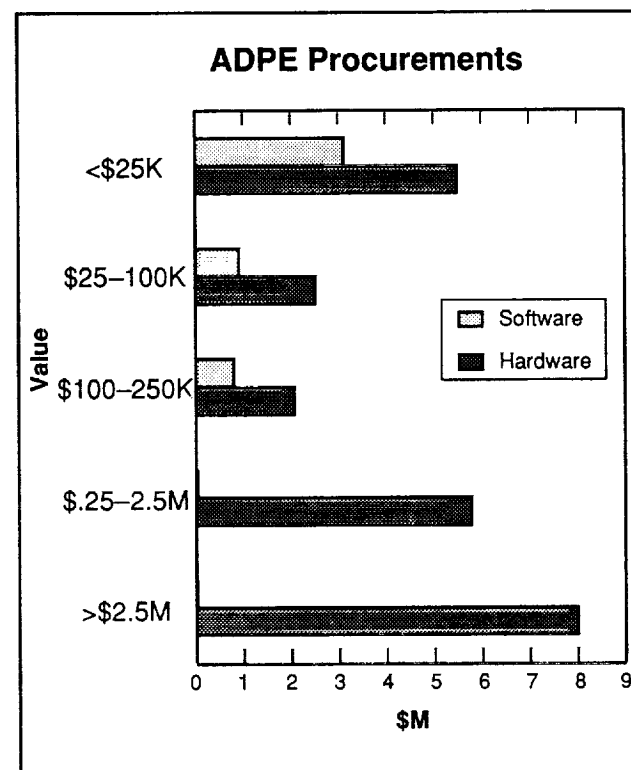
- User frustrations (P-9)
- Data deficiencies in procurement requests (P-9)
- High initial rejection rate (70 percent) on FIPs procurements
- Technical evaluation delays (P-15)
- SEB/C learning curve

Suggest forming a NET with S&E EM, Labs, AP20, CN41, and BF30 to further examine expediting procurements and training for center personnel in the overall process, rationale for requirements, and the specifics of procurement request preparation and evaluations.

The multiplicity of procurement processing and tracking system (S&E ordering system, APRS, BCSS-CAMS, PROMIS, etc.) should be consolidated to provide end-to-end tracking. APRS seems like the best

vehicle to adapt, through incorporation of the procurement office functions. BCSS should be encouraged to use APRS or FIPs procurements. Until APRS, with its user accessibility for status, is fully implemented, initiators should be kept informed of procurement status.

Buyers/negotiators should verify the content of requests (RFQ, RFP, IFB) and responses (quotes, proposals, for bids) with the initiator before consummation of contracts.



## Notes

Almost all software and hardware procurements are within the MSFC approval authority and the preponderance are small purchases; thus, there is real opportunity for streamlining the system:

	Software	Hardware	Combine	Number	Amount
<\$25 k	≈96%	≈91%	≈94%	1,813	≈\$9.4 M
\$25–100 k	≈3%	≈7%	≈5%	101	≈\$4.3 M
\$100–250 k	≈1%	≈1%	≈1%	19	≈\$3.6 M
\$0.25–25 M	–	≈0.3%	≈0.2%	4	≈\$6.1 M
>\$25 M	–	≈0.2%	≈0.1%	2	≈\$8.1 M

Assignment of all off-the-shelf software and hardware procurements <\$25 k to BCSS would nearly eliminate the demands on the procurement office for FIPs resources. Eventually the level could be raised to \$250 k, which is also consistent with the headquarters requirement approval of any restrictive competition.

## FIP (ADPE) Procurements

- Seek sensible relief from statutory and GSA constraints.
- Streamline ISO/BCSS review process. (NET)
- Eliminate PMD screening to ADPE.
- Assign all off-the-shelf ADPE procurements <\$25k to BCSS.
- Streamline FIP acquisition plan approval.

## Notes

The regulations applicable to FIPs resources are ever expanding. While the motivation to achieve thorough planning, uniformity competition is good, the process is counter productive. Innovative steps can and are being made within the regulations, but the issue needs to be addressed at the agency and congressional level. The center director can approve most procurements up to \$25 M, but only to \$2.5 M for FIPs.

The review process within ISO and BCSS can involve two dozen persons for procurements >\$250 k. A NET is being formed to further examine the process with the

expectation of making major revisions. The potential exists to reduce the number of steps by at least half.

Due to the rapid obsolescence of ADPE, screening surplus lists for requested items has a success rate of an 1 percent (61 items valued at \$219k). GSA has discontinued cataloging items <\$1M (FIRMR 201–33.001); there is little value to screening agency surplus. The Property Management Division (PMD) screening, on average, adds 3–4 days to the procurement processing.

The Long Form Acquisition Plan review and approval (currently involving up to 23 people) should be limited to AI01; Chief, Procurement Policy and Review Branch; Deputy Director AA01; and the center director. Information copies might be provided to others. The cover letter should be replaced by a routing slip for center level approvals.

## Contract Acquisitions (Mission, Service, Facilities)

- Most contracts are let at the end of the fiscal year, and little cost is accrued.
- Sound facility design is compromised by the funding approval cycle and immaturity of requirements.
- Technical evaluation delays are not uncommon.

## Notes

Facility engineering and design dilemma

Congressional appropriation bill	≈November
Headquarters decision meetings	Mid-December
Project funding approval	January–February
Contract award	≈May
Results for next budget cycle	Mid-July
Finalization of budget data	October



## Contract Acquisitions Potential Enhancements

### Contracts

- Fund contracts and purchases, especially for S&E, early in the fiscal year. Earmark funds for specific procurements.
- Baseline facility requirements for PER.
- Advance headquarters PER approvals and/or center procurement preparation. (NET)
- Develop evaluation forms and stress priority of technical evaluations.

### Notes

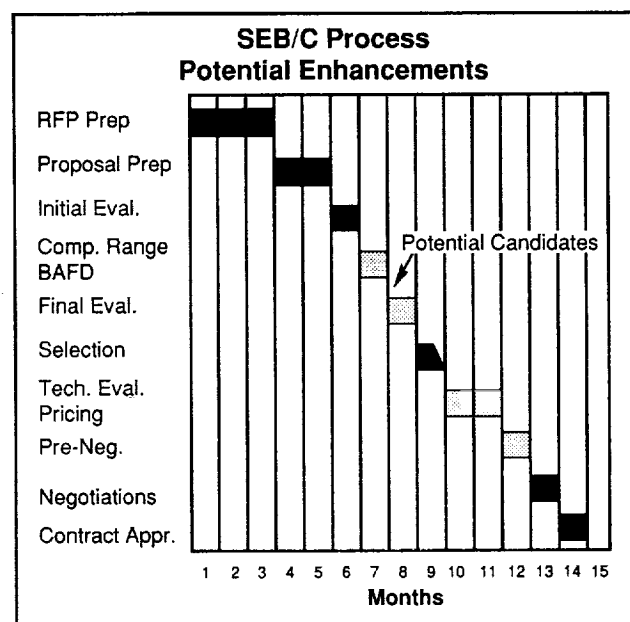
Institutional and Project Operating Plans need to provide early fiscal year funding for contracts and purchases so that awards can be made and cost (as well as results) accrued. Project funding should be **transferred** to S&E, or other offices in the first quarter of the fiscal year that funds can be earmarked for procurements; if funds are not committed by the second quarter of the fiscal year, they could be recalled and reprogrammed. Rather than in-line project approval of procurement requests (MMI 5101.5F, attachment B), information copies should be used.

A facility user requirements document should be under a form of configuration control starting with the PER solicitation, and strong user input is needed early in the design.

Making Preliminary Engineering Report (PER) funds available in first quarter fiscal year and/or completion of procurement packages for release upon funds approval should be explored with headquarters codes H and NX. Some "wasted" effort is to be expected. A NET within facilities and procurement offices is suggested. A stronger code M advocacy for facility projects would be beneficial.

Delays in finalizing technical evaluations are due both to inadequate guidance for and low priority by the evaluators. Clear instructions and samples should be provided by the Procurement Office, and management should stress timeliness. A "fill in the blanks" form based upon the RFP criteria should be used for non-SEB/C proposal evaluations. Specific deadlines and status checks are needed to preclude stagnation.

## SEB/C Process Potential Enhancements



### Notes

Statutory and policy time stipulations, together with maximum compression of all other events, yield the:

	Minimum Elapsed Time	
	SEB	SEC
Regulation	80 days	65 d
NASA Policy	61	24
MSFC policy	14	9
Evaluation (initial and BAFO)	40	40
Other	<u>27</u>	<u>16</u>
	222 d	154 d

In reality, the elapsed time is nearly doubled:

Historical	≈410 d	≈350 d
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The greatest potential for streamlining is in minimizing the written/oral discussions and BAFO cycle, and the post-selection activities.

### Programmatic Requirements

- Put emphasis on programmatic review of RFP (WBS, SOW, Specifications).
- State Government "requirements" as such.

- Focus evaluation subfactors and proposal instructions on programmatic risks.
- Minimize contract documentation.

## Notes

The programmatic and technical material is the RFP should be thoroughly reviewed for comprehensiveness and consistency to assign **total** responsibility to the contractor (unless there are specific NASA tasks). The WBS should be structured to logically organize work authorization and cost collection. The programmatic review takes on new importance with the trend toward smaller SEB/C's; the review might be accomplished through the advisory council or, perhaps, a group empaneled from various organizations.

When the Government knows, from experience, how they want the project structured, it should be stated in the RFP rather than leaving it open as a pseudo-discriminator. Reprogramming during negotiations is questionable.

In recognition of prior problems on major programs, suggested mission suitability subfactors are provided on the **next page** to address those issues. Standard, but not flexible, **guides** for subfactors and proposal preparation instructions could be developed for the various types of contracts.

Deliverable documentation competes for funds with other work and should be minimized with the lowest possible approval level. Consideration should be given to substituting presentations (revised and baselined) for most of the "plans." Deliverables should be limited to those needed for Government action, accounting, authorization, or archiving. Current efforts to standardize documentation requirements should be expedited.

## SEB/C Process (general)

- Consist with smaller SEB/Cs, the center must assign top people and provide staffing.
- Consider a permanent SEB/C group.
- Standardize cost proposals (include in page limitations). (NET)
- Limit plans delivered with proposal.

## Notes

A permanent SEB/C group, augmented by specialists, would be consistent with reducing the size of evalua-

tion teams and improving productivity, and would provide continuity and opportunities for standardization of documentation and evaluation techniques. The organization should encompass recorders, general management and business analysts, general technical analysts, and cost analysts. While the board should not be permanently staffed, some membership from the organization, perhaps the management and technical committee chairpersons, should be included for continuity and efficiency.

Simplification of cost proposal requirements can be done and would be of mutual benefit to the Government and industry. In effect, two cost proposals (contractor and Government fiscal year) are required for pricing and SEB evaluation. The need for a common data base is obvious, and would be an appropriate topic for a NET. Insistence on total scope control could deemphasize the cost proposal detail and focus on program content, integration, and control. With the use of diskettes for data, cost proposals should be included within proposal page limitations.

Deliverable plans should be limited, for example, to development and verification, manufacturing, and facilities, (if substantial).

## SEB/C Process (general) (continued)

- Streamline past performance and key personnel evaluations.
- Insist on good initial proposals and minimized discussions and BAFO.
- Expand inclusion of pre-negotiation objectives in the SEB/C presentation.
- Use SEB/C report in lieu of technical evaluation and pricing report.

## Notes

Past performance—proper emphasis contemplated a uniform data base which never materialized (but, if continued, should be developed); current process is time-consuming and findings are very subjective, and, generally, inconsequential. Procurement office could screen offeror's for debarment, ineligibility, suspension, and contract terminations (lack of prior Government or NASA contracts by the **performing activity** should be noted under experience).

Key personnel—eliminate as a separate subfactor, except, possibly, for service contracts, and treat distinct strengths and weaknesses as part of the management

subfactor. Fact finding is time-consuming and highly subjective.

Emphasize clause 52.215-16 Contract Award (April 1985), and restrict discussions, if compelling, to items such as terms and conditions. The agency should move, through regulatory changes, toward maintaining BAFO submission a Government option rather than a necessity.

A separate technical evaluation and pricing report may be required for major fact finding changes; but, pricing data could otherwise be a part of the SEB/C report, especially for total scope control.

## Major System Acquisition

- Buy-in syndrome.
- Inadequate and unstable early year funding.
- Inadequate systems engineering.

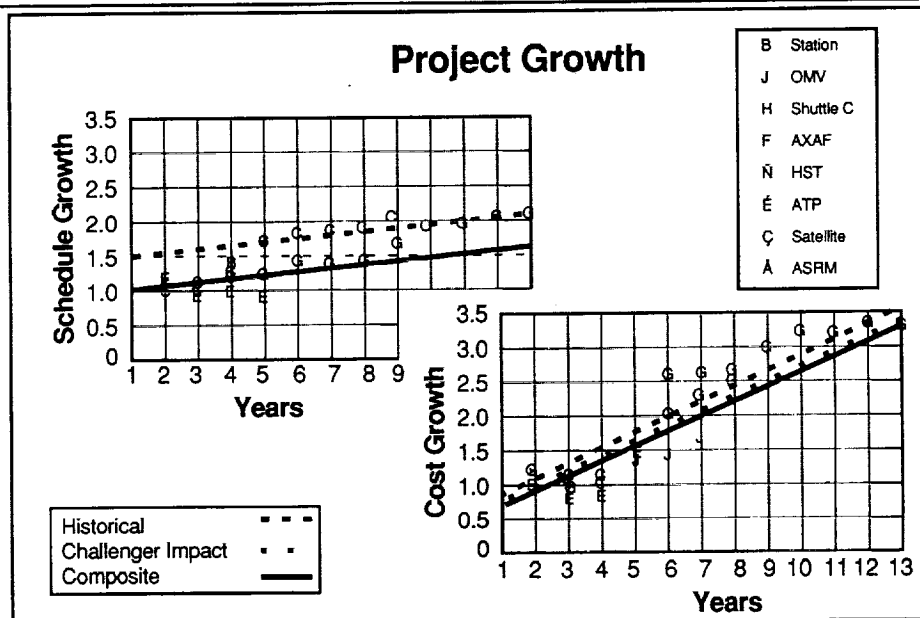
- Inadequate design margins.
- Inadequate attention to manufacturing and operational requirements in design.
- Inadequate programmatic discipline.

## Notes

The most prevalent causes of project problems were compiled from discussions with project managers and others.

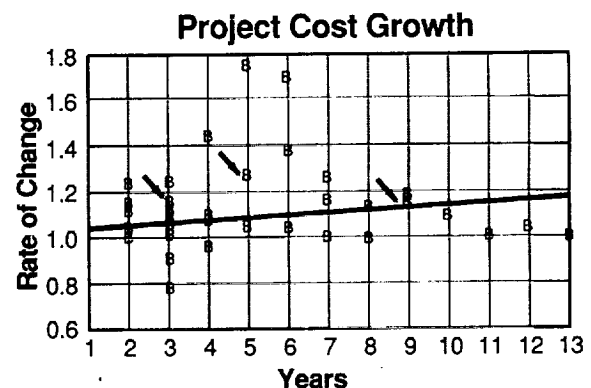
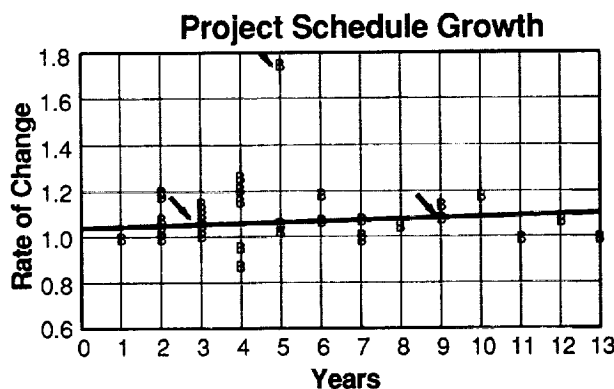
These observations are supported by an assessment of the sources of program cost growth on a number on a number of projects (page 23).

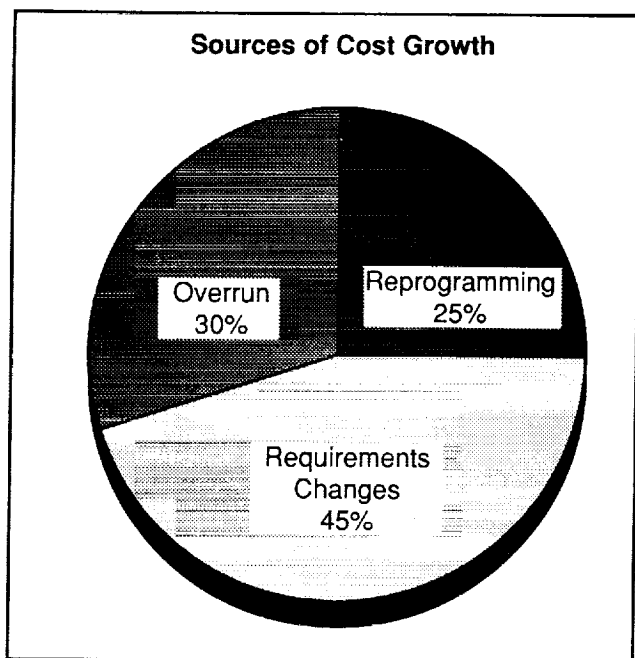
None of these issues is a "breakthrough;" each has been addressed in existing policies, procedures, or handbooks; but, there is obvious evidence of laxity in implementation.



## Notes

Normalized DDT&E runout cost and first flight date projections taken from annual POP's show surprisingly consistent growth factors.





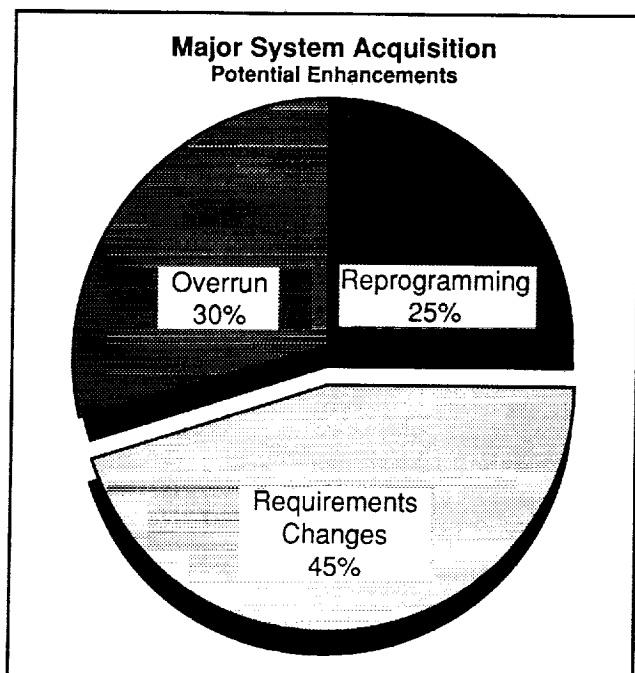
### Notes

An analysis of project cost growth factors for a number of projects reflects the following trend:

Requirements changes	≈45%
OVERRUNS	≈30%
Reprogramming	≈25%

These data are supportive of the principal causes of project problems derived from discussion with project personnel.

Considerations for mitigating these growth factors are addressed on the following charts.



## Major System Acquisition Potential Enhancements

### Requirements definition

- Strengthen phase A and B study teams.
- Revitalize system engineering.
- Fund phase A and B studies adequately for:
  - Detailed system and program analyses, and subsystem design concepts
  - Proof of concept and processes.
  - Environmental impact and institutional requirements analyses.
- Better utilize pre-development reviews.

### Notes

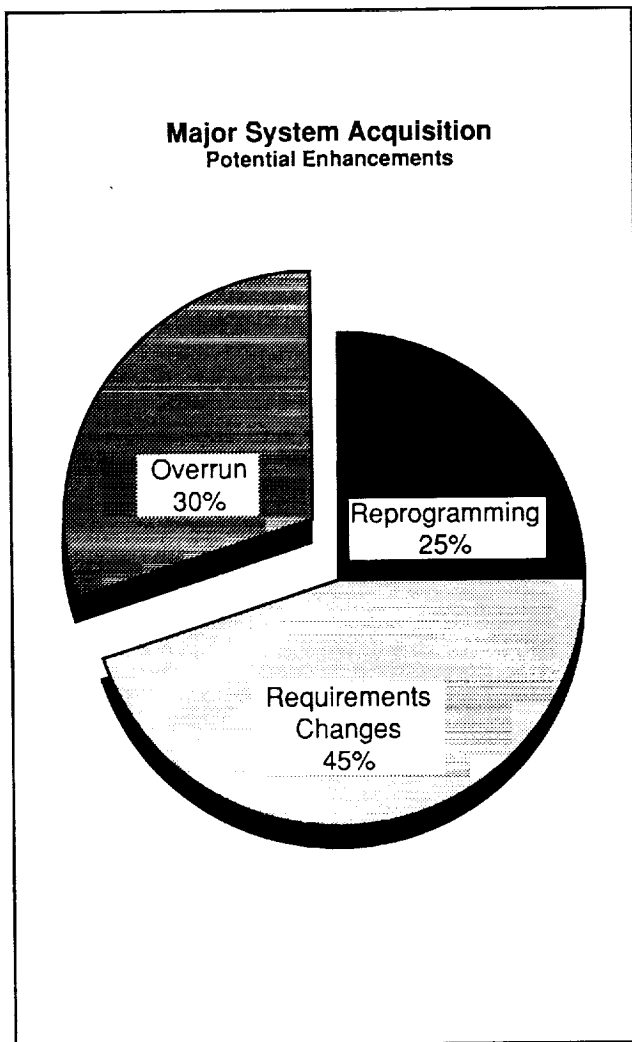
Phase A and B study teams need greater involvement from S&E, SRM&QA, and the anticipated project management and engineering personnel, as well as personnel from influencing centers and projects to establish comprehensive requirements.

Systems engineering, here, is meant to be the continuing, interdisciplinary, technical and programmatic analyses, of: **requirements** and sensitivities; **technical risks** and mitigation; design **margins**; design **functionality** in terms of optimum manufacturability, operability, and maintainability; **design solutions** and **problem resolutions** in terms of total system simplicity and integrity; **test planning** to achieve nominal and off-nominal characterization; and **performance** in terms of repeatability, reliability, and design feedback. Things like design evolution reviews (PRR, PDR, CDR...) and configuration management must be recognized as **TOOLS** of system engineering.

Empirical proof of concept work and risk analyses should embrace any new materials, processes, or technology in general, and include breadboards, etc...

The stringency of current and future environmental constraints may influence construction, manufacturing, and test operations, and must be included in phase A and B studies to determine any design or programmatic impacts. Similarity, institutional impacts need to be identified to preclude implementation delays.

Thorough pre-development reviews should be used in preparation for the headquarters acquisitions and the non-advocate reviews.



### Overrun Mitigation

- Establish initial project estimates as ranges with reassessment and commitment at CDR.
- Strengthen RFP requirements for comprehensive, integrated implementation planning.
- Insist on budget contingency, and give project manager reasonable flexibility.
- Insist upon use of PMS discipline.

### Notes

Project cost commitments are made too early in the definition phase (years before receipt of proposals) to have long-term credibility. Initial cost and schedule estimates should be given as ranges. Cost estimates must be reviewed for comprehensiveness (project and institution support for all centers, impact to other projects, operational impacts, etc.). Phase C/D contracts should encompass the entire DDT&E, but be

structured in detail through CDR with a requirements for submittal of cost and schedule estimates-to-complete at that time. The Government would evaluate the proper course of action (continue, restructure, terminate), and, unilaterally, reconsider the fee structure based upon the contractor performance and external project impacts. There is too much cost and schedule pressure at the beginning of Phase C/D for sound management.

Contractor buy-in must be discouraged, in part through the RFP, by de-emphasis of the cost factor through stressing integrity and comprehensiveness of program planning, and by insisting that cost estimates be based upon total scope accountability with few, if any, anticipated changes; and by disqualification of unreasonable cost estimates. (see page 19)

Budget estimates and commitments must include reserves for changes and growth. Based upon the offeror estimate and project complexity, the reserves could be significant. Project managers should have realistic contingency each year for effective management.

The most important aspect of PMS is the management discipline that it imposes. Contractors can maximize the currency of the data reports.

### Overrun Mitigation (Continued)

- Implement total scope control rather than design control.
- Maintain project management continuity.
- Strengthen business management capability (or acquire support service contractor(s)).
- Change penalization of underruns.

### Notes

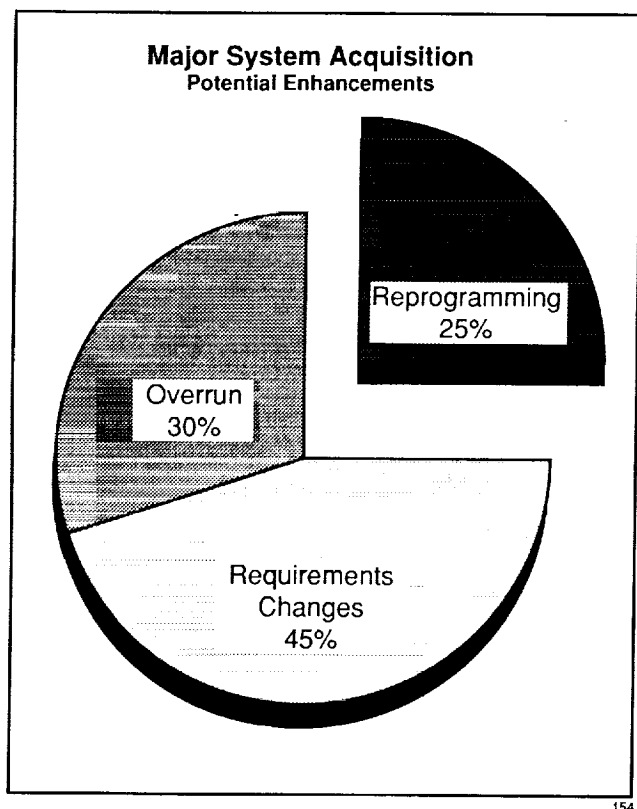
The Government assumes too much responsibility for contract mission objectives prior to qualification; thereby, causing excessive change traffic (see page 7). Approvals of documentation and design review should confirm compliance and adequacy; the contractor is to maintain configuration control. Out-of-scope changes should be restricted to the CEI specifications or ICD's, quantity of deliverable, or schedule accelerations. Total scope control will not preclude cost growth, but both in-house and contractor administrative costs should be reduced. Award fee would be a more powerful management tool.

Project personnel should be assigned during phase B studies to establish and maintain strategies for the

program. Ideally, the project manager and chief engineer should be on the SEB. When the inevitable problems occur, removal of in-house or contractor management should be avoided unless there are also fundamental changes in direction.

The comptroller's office training program will begin to address the need for program analysts, but the business management capability must be addressed broadly. Training and discussion forums would be beneficial for current analysts to share experiences and techniques. Business management areas should be evaluated to determine where selective hiring would strengthen the center.

Current budgetary practices promote compliance with the annual cost plan rather than results; thus, there is little incentive to save money.



### Reprogramming Mitigation

- Stabilize early year ( $\approx 3$  years) funding and stipulate in RFP (headquarters commitment).
- Defer contractual reprogramming until impacts are really known, if early year funding does change (e.g., PDR or CDR)

### Notes

The agency tendency is to "aft load" the funding of

development projects, whereas early expenditures are required to establish a sound technical base and preclude later cost growth due to deferred risk.

The vacillation of early year funding guidelines is more detrimental than a lower, but known, funding schedule, since it drains manpower for "what if..." studies and continuous reprogramming.

It would be more prudent to commit to fiscal year funding levels through CDR and reassess the estimate-to-complete at that time. There would be adequate maturity at CDR to effect any needed reprogramming for the remainder of the DDT&E, and reprogramming impacts (other than schedule **acceleration**) would be minimal prior to CDR.

### Alternate Acquisition Approach

Down selection from multiple, adequately funded phase B studies to a single phase C/D contractor.

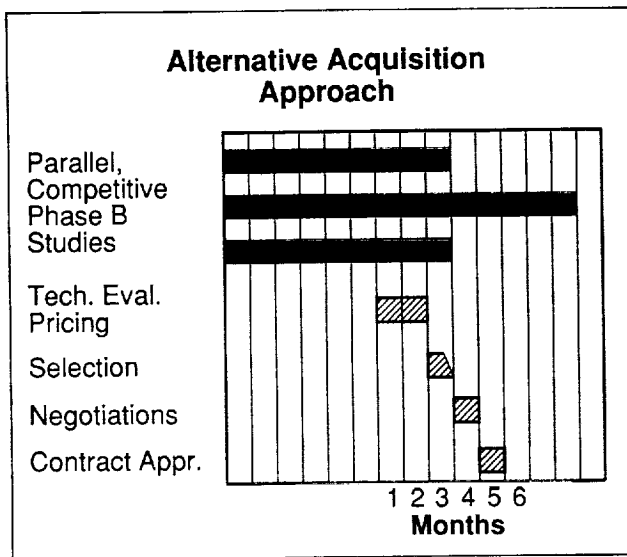
- Could make phase B studies more realistic and reduce risk for phase C/D
- Could provide more substantive data for selection.
- Should substantially reduce the "procurement process" and selection time.
- Should make better use of contractor resources (IR&D and B&P).

### Notes

Following the **concept** of OMB circular A-109, major system acquisitions, down selection from multiple, competitively selected phase B study contracts to a single phase C/D contractor could improve the technical and programmatic maturity going into certain, but not necessarily all, phase C/D programs, and significantly reduce the transition (procurement) period between the two phases.

- Contractual, and political, provisions for down selection would have to be addressed in the phase B competitive procurement.
- The NASA proposed phase C/D contract would be provided to phase B contractors, perhaps, midway through the study.
- Final study report, encompassing the preliminary design concept and rationale, CEI specifications, proof of concept results, and phase C/D implemen-

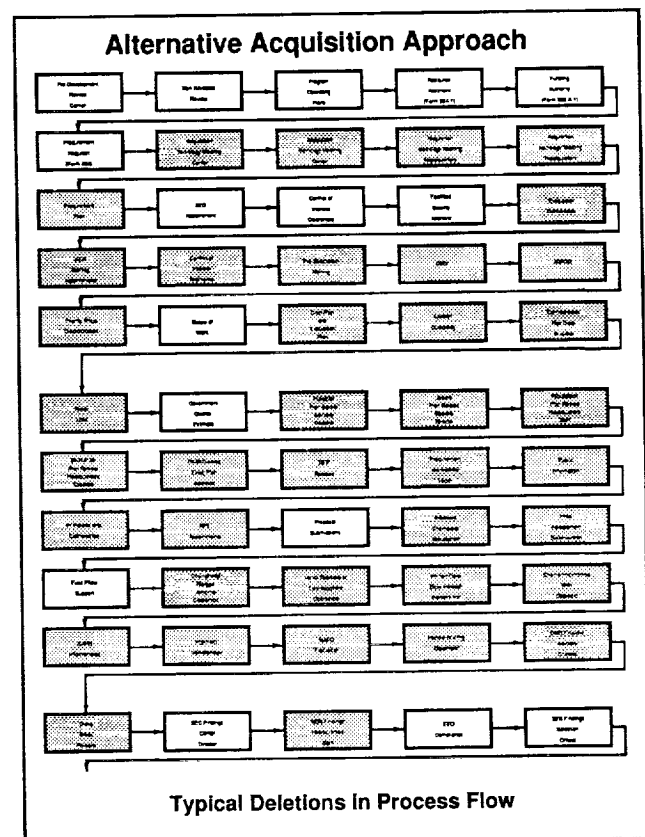
tation plans, as well as deviations to the NASA proposed contract and Form 1411 cost proposal would constitute the phase C/D proposal.



## Notes

Greater maturity of design, development, and planning resulting from more intense phase B studies should contribute to phase C/D requirements and programmatic stability. Down selection would preclude a contractor from holding back features for the phase C/D proposal (or BAFO).

Contractors, and NASA, would be motivated to assign anticipated project implementation personnel during phase B. Contractor teams could be maintained throughout the ≈3 month technical selection period (direct funding or B&P) to finalize detailed, integrated program plans (cost, schedule, content) for negotiations and for PMS baseline, with the stipulation that the previously proposed cost and fee (Form 1411) are for **total** accountability.



## Notes

A down selection process would necessitate the same objectivity and discipline as the current SEB process, but a significant number (≈60 percent) of the competitive procurement steps could be eliminated (dark boxes in the extract from the flow chart).

- A panel or SEB would report findings to a source selection official.
- Preponderance of solicitation steps would be eliminated.
- Discussions and BAFO would be eliminated.
- A source selection statement would be required.
- Debriefings would be granted.

Principal source of a protest would be an allegation of transfusion of prejudicial information during the phase B study. Given the NASA culture to strive with each contractor towards the best solution (a major departure from a tenet of OMB Circular A-109 implementation), selection criteria would have to be desensitized to transfusion. Selection might be based upon adequacy of system engineering, design maturity and compliance with specification requirements, program risk, phase C/D implementation plans, responsiveness to

proposed contract, demonstrated team performance, and cost proposal (simplified).

## Acquisition Enhancement Survey

- Positive steps are being taken.
- Significant opportunities exist for further enhancements
  - Suggested action plans.
  - Recommended NET formation.
  - Cultural changes are needed.
- Exchange of ideas with headquarters and other centers should be pursued.

### Notes

Flow charts for each type of procurement surveyed provide center-wide reference tools, and identify specific opportunities for streamlining.

Suggested action plans for center organizations have been derived from the survey findings. The active use of NETS within and across organizations would likely focus additional potential for streamlining.

Streamlining of the acquisition process and application of TQM entails cultural changes:

- Management needs to demonstrate trust in and respect for the work force.
- Responsibility and authority must be delegated to lowest levels.

- User (initiator) organizations must relate to “service organizations” as professionals and equals.
- “Service organizations” must offer timely solutions, not road blocks, to achievement of user objectives.
- Project offices should adopt total scope control of contracts.
- Over conservatism in policy and positions must be bridled.
- Team building should be improved through personnel mobility.
- Opportunities must be exploited to recognize the work force.

## Culture Changes

- Demonstrate trust in and respect for the work force.
  - Delegate responsibility and authority.
  - Respect right to err.
  - Exploit opportunities to recognize workforce.
- Improve team building.
  - USER: recognize service organizations as professionals; and SERVICE: offer timely solutions, not road blocks.
  - Maximize inter-office mobility and NETS.
- Adopt “total scope” contract control.
- Bridle over conservatism in policy and positions.







## Interviews

Don Bean	– Director, Administrative Operations Office	Alex McCool	– Director, Safety and Mission Assurance
J.A. Bethay	– Associate Director, MSFC	Dr. George McDonough	– Director, Science and Engineering
Porter Bridwell	– Manager, Shuttle Projects Office	Royce Mitchell	– Project Manager, ASRM
Eddie Bryan	– Chief, ASRM Productivity Engineering	Sammy Nabors	– Productivity Improvement Office
John Chapman	– Deputy Project Manager, ASRM	David Nicholas	– President, MESA (MSFC union)
Keith Coates	– Chief Engineer, ASRM	Jack Nichols	– Former ASRM Chief Engineer
Jimmy Crafts	– Chief, ASRM Systems Engineering and Integration	Emil Posey	– Chief, RSMR Contracting Officer (Procurement)
Bob Dunn	– Shuttle-C Task Team	Susan Smith	– Chief Council (Legal)
Bill Eoff	– Deputy Manager, Shuttle-C Task Team	Doug Thomas	– Productivity Engineering, ASRM
Glenn Eudy	– Manager, Shuttle-C Task Team	Jack Walker	– Shuttle-C Task Team
Bill Hallisey	– Comptroller, MSFC	Ray Woods	– Chief, ASRM Contracting Officer (Procurement)
Ed Henke	– Director, Procurement	Lowell Zoller	– Staff Member, MSFC Director's Staff
Larry Lechner	– Productivity Improvement Office		
Jack Lee	– Center Director, MSFC		







## Summary

### Motivational Principles in Use

The purpose of this questionnaire is to determine the motivational principles and theories most favored by today's managers. Please read each description carefully and mark the appropriate category. Indicate your level of management in your local organization struc-

ture in order to help categorize results. This questionnaire is completely confidential and will be sent to a number of managers in your organization thus making your response anonymous.

5 First Level Mgmt

4 Middle Level Mgmt

2 Top Level Mgmt

Check any appropriate box

	Unfamiliar	Familiar	Use
<b>Herzberg's Theory of Job Satisfaction –</b> Motivators versus hygiene factors	6	5	3
<b>Maslow's Hierarchy of Needs –</b> Physiological, safety, belonging, esteem, self-actualization	3	8	5
<b>McGregor's Theory X &amp; Theory Y –</b> 2 basic assumptions on human behavior	4	7	3
<b>Managerial Grid –</b> Graph of production concerns versus concerns for people	9	2	1
<b>Likert's System IV –</b> 4 systems to categorize organizations	10	1	0
<b>In Search of Excellence –</b> Eight basic principles to stay on top	4	7	2
<b>McClelland's Achievers –</b> Scoring people's need for achievement	9	2	1
<b>Porter &amp; Lawler's Satisfaction Theory –</b> Performance -> rewards -> satisfaction	7	4	1
<b>Likert's Team Management –</b> Linking pin concept to link management teams together	11	0	0
<b>Vroom's Valence Theory –</b> Motivation = sum of valence x expectancy	11	0	0
<b>Max Weber's Bureaucracy –</b> Division of labor and small span of control in org. structure	9	2	0
<b>MBO -</b> Management by objectives	1	10	4
<b>Quality Circles -</b> Voluntary problem solving teams	1	10	3
<b>Hersey &amp; Blanchard's LASI –</b> Situational management	9	2	1
<b>Tannenbaum &amp; Schmidt's Leadership Patterns –</b> Democratic versus autocratic	8	3	2
<b>Ouchi's Theory Z –</b> Japanese approach to motivation	10	1	1

14 Surveyed – 11 responses

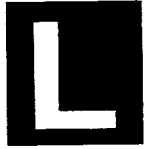




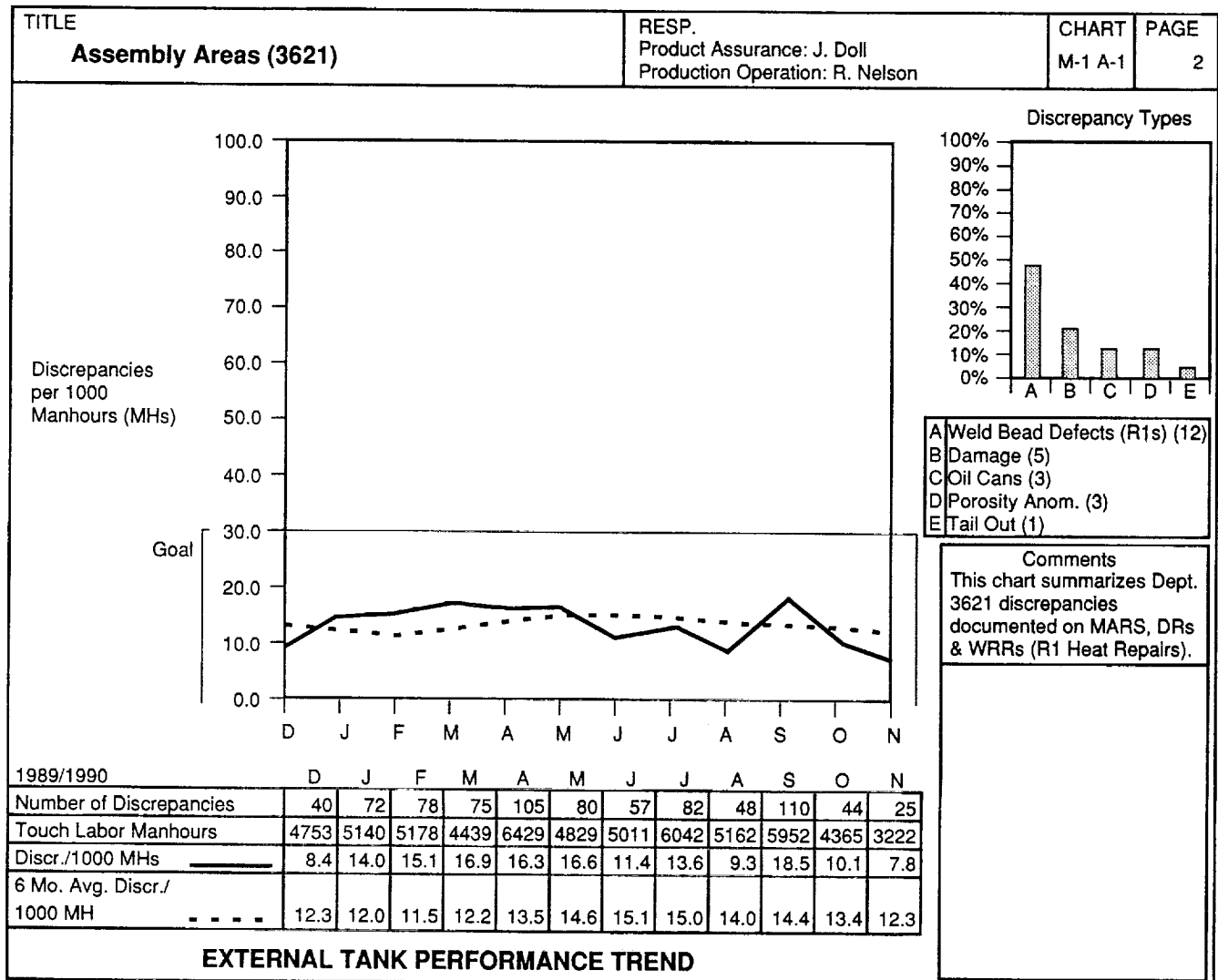
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## Appendix

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**Comments**

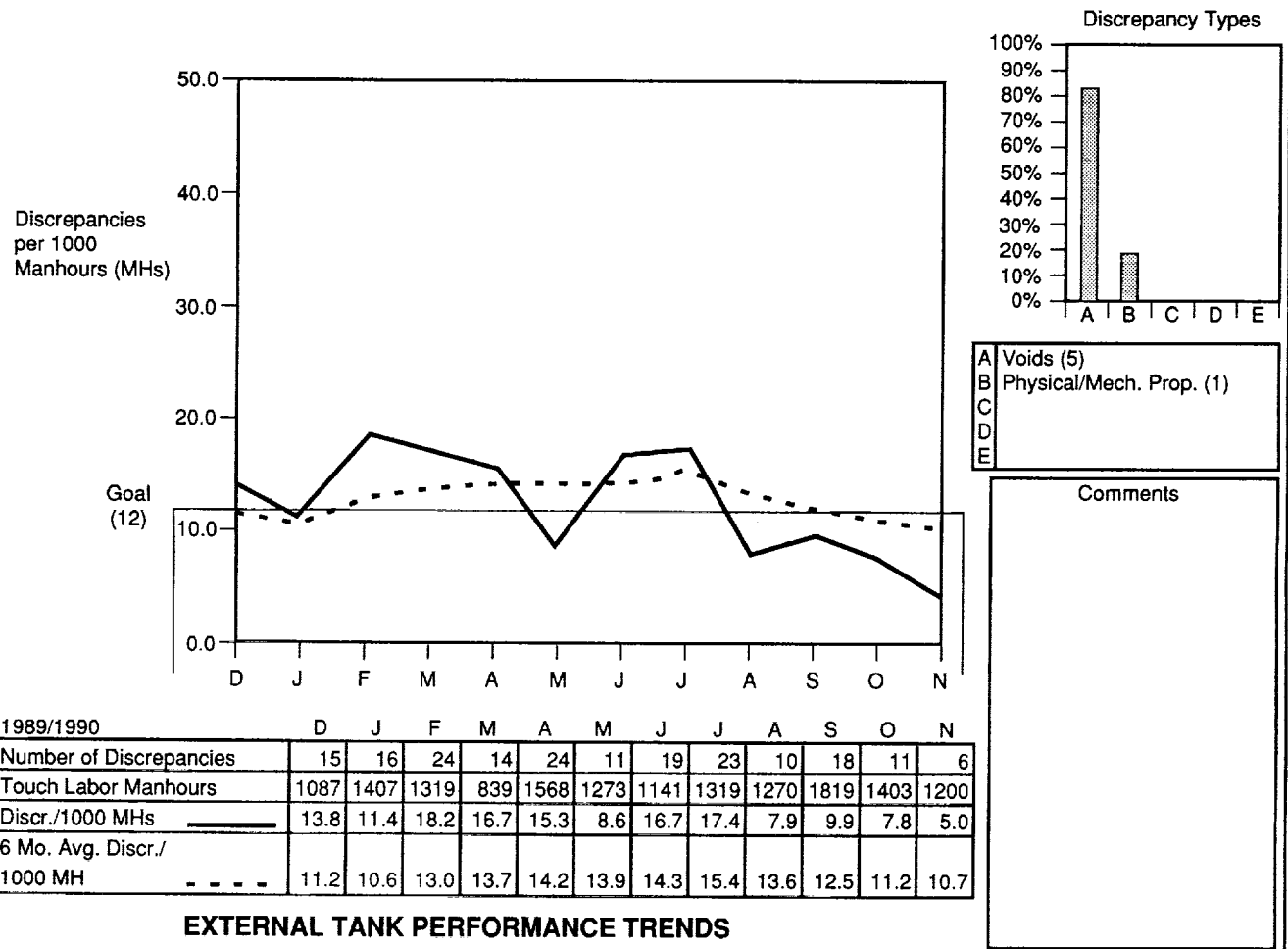
This chart summarizes Dept. 3621 discrepancies documented on MARS, DRs & WRRs (R1 Heat Repairs).

**TITLE**  
**SOFI Shop (3673)**

**RESP.**  
Product Assurance: T. Pettit  
Production Operation: J. Litfin

**CHART**  
M-1 B-2

**PAGE**  
5

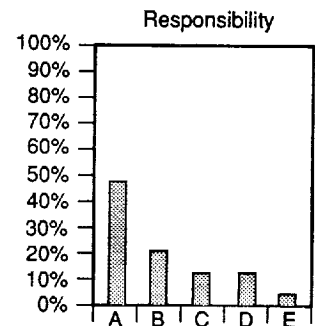
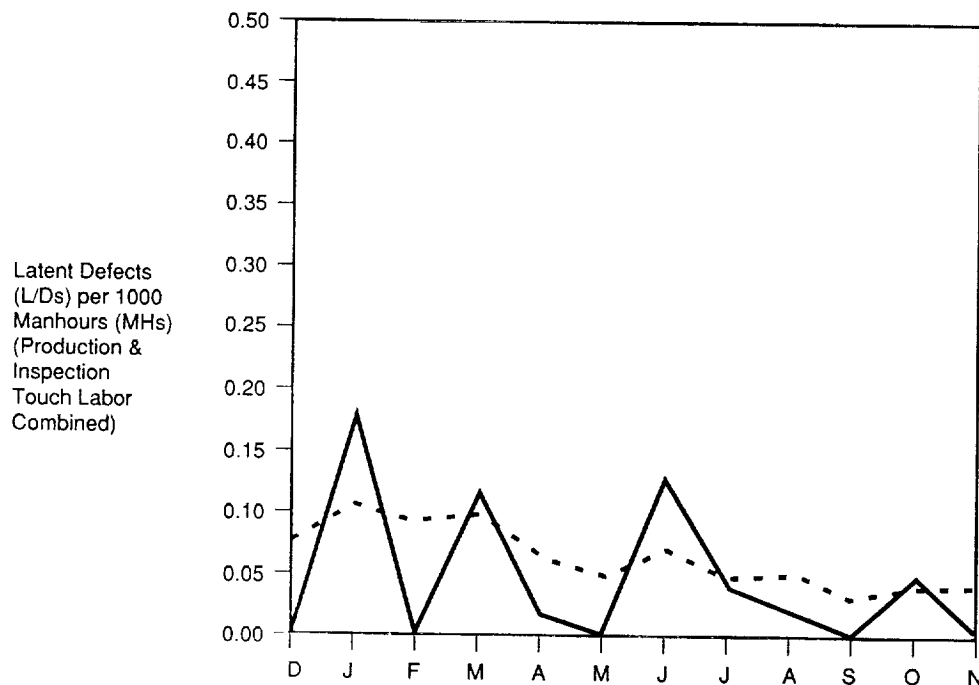


**TITLE**  
**Production In-House Latent Defects**

**RESP.**  
 Product Assurance: R. Willoughby  
 Production Operation: P. Donohue

**CHART**  
 N-1. C

**PAGE**  
 16



A  
B  
C  
D  
E

**Comments**  
 Data from this chart is obtained from MARS which are coded LXXX for Department Liable. Displayed are the responsible departments (if identified), as well as a brief description of the defect.

1990	D	J	F	M	A	M	J	J	A	S	O	N
Number of L/Ds	0	8	0	5	1	0	6	2	1	0	2	0
Touch Labor Manhours (K)	41	45	46	41	58	49	46	55	46	54	40	33
L/Ds per 1000 MHs	0.00	0.18	0.00	0.12	0.02	0.00	0.13	0.04	0.02	0.00	0.05	0.00
6 Mo. Avg.	0.08	0.11	0.09	0.10	0.06	0.05	0.07	0.05	0.05	0.03	0.04	0.04

**EXTERNAL TANK PERFORMANCE TRENDS**





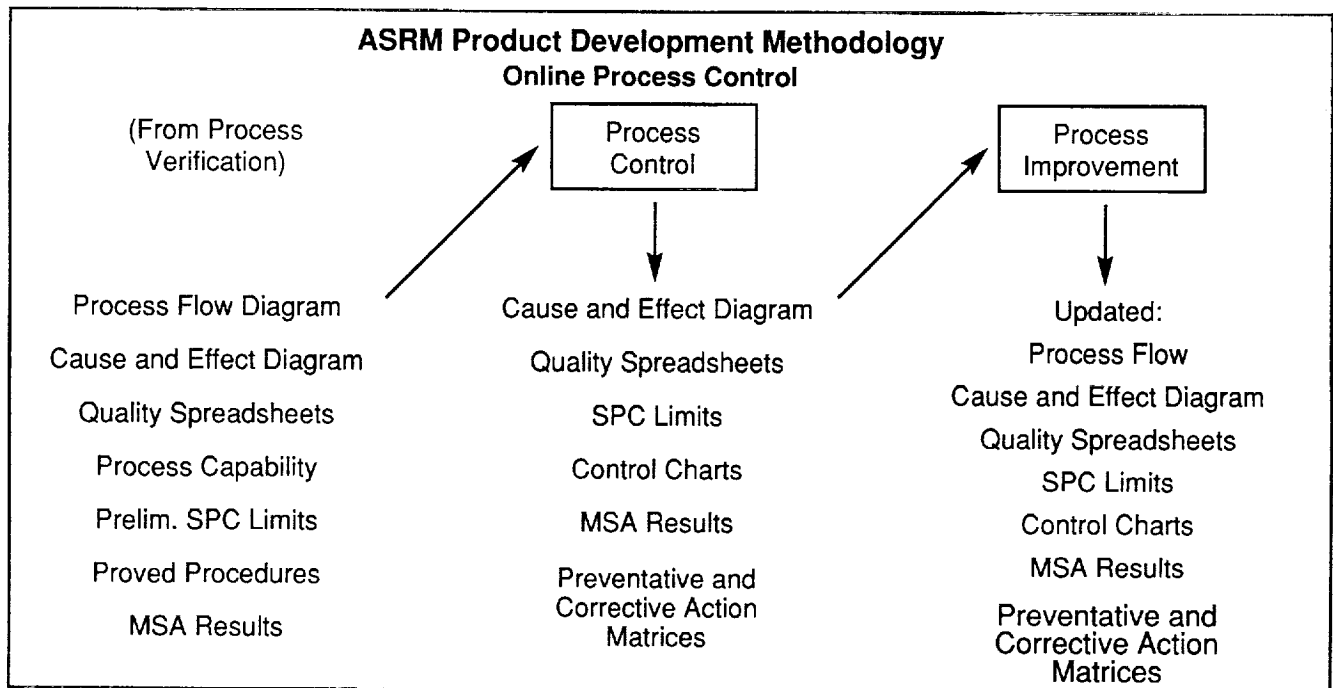
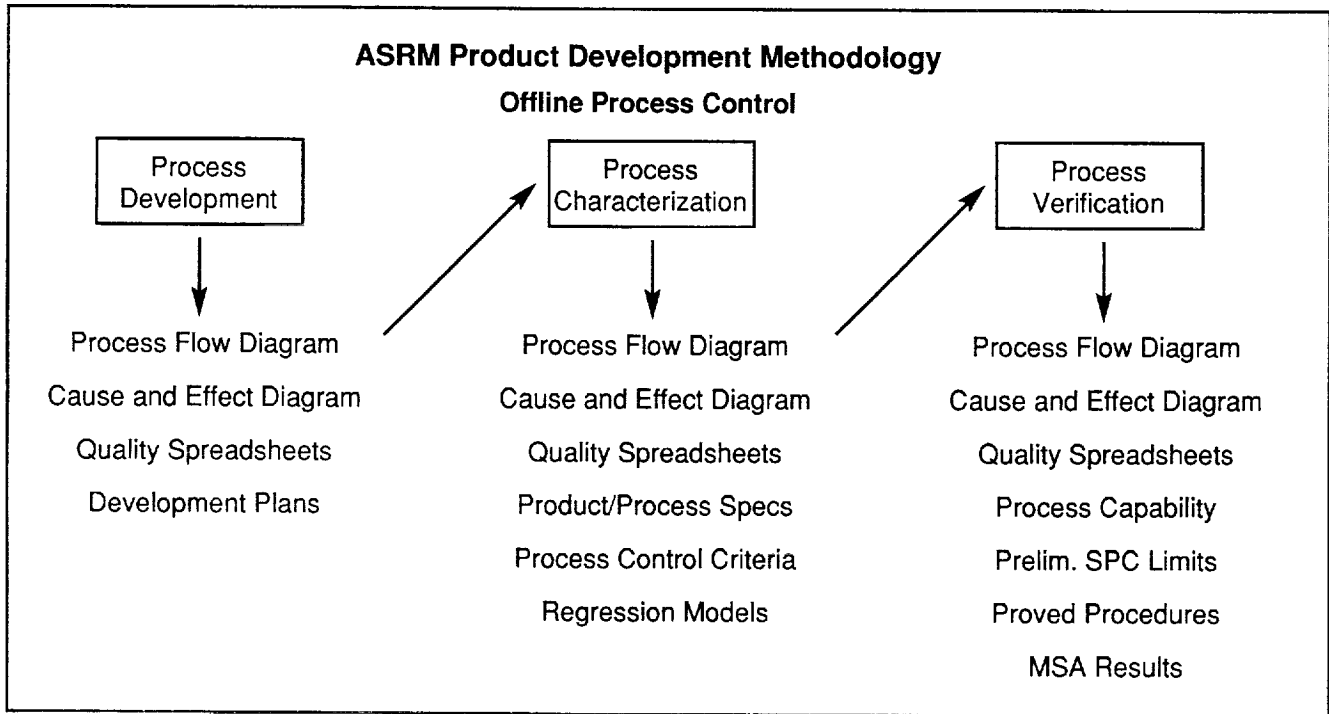




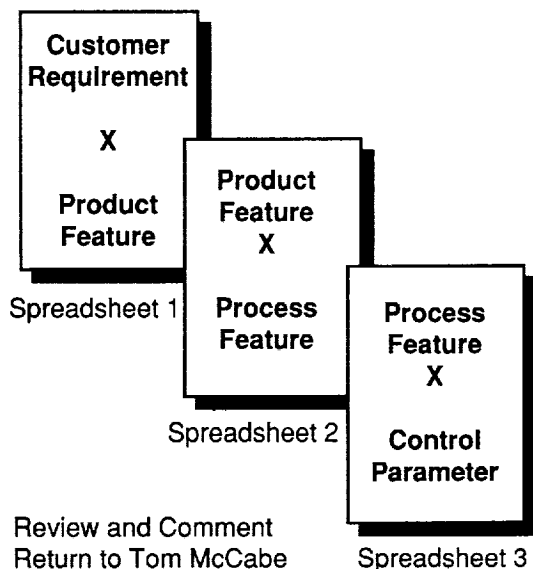
# ASRM Product Development Methodology

## 5 Phase Process Control Program

- Development—Perform system design and begin quality planning
- Characterization—Perform parameter and tolerance design, begin analysis of measuring system, SPC plan
- Verification—Process proofing, measurement system verification, process capability analysis
- Control—Process control procedure, SPC
- Improvement—Project teams, 12 step program



**19 September 1990**



PRELIMINARY

**Liner Preparation and Application Quality**  
**Planning Customer Requirements**  
**X Product Features**

	Product Features			
	X Product Features			
	Storage Condition	Liner Composition	Liner Thickness & Weight	Cure
Propellant/Liner/Insulator Bond Strength in Required ASRM Environments	3	3	3	3
Process Verification Testing	1	3	3	3
Liner Weight	0	3	3	0
Reliability	1	1	0	0
Safety	1	3	3	3
Cost	1	2	2	1
Schedule	1	0	0	1

## Liner Preparation and Application Quality Planning

Product Feature	Process Feature																													
	Applicator Standoff Distance	Applicator Traverse Rate	Atomizing Air Nozzle Configuration	Atomizing Air Nozzle Orientation	Atomizing Air Nozzle Pressure	Cure Air Flow Rate	Cure Particulate Contamination	Cure Temperature	Cure Time	Density	Dispersion of Carbon Black	Fluid Flow Rate	Fluid Nozzle Configuration	Fluid Nozzle Service Life	Fluid Pressure at Applicator	Handling Hazards	Melting	Mixing (Inline)	Mixing (Stirring)	Segment Rotation	Shear Life (Ingredients)	Spray Pattern Width	Temperature (Ingredients)	Vacuum (Praliner Mix Cycle)	Viscosity (Praliner)	Viscosity (Praliner & Curalive)	Weight Ingredients			
Storage Conditions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	3	0	2	0	1	0	0			
Liner Composition	0	0	0	0	0	0	0	0	0	3	2	3	0	0	2	1	2	3	3	3	0	1	0	3	1	1	2	3		
Liner Thickness & Weight	2	2	3	3	3	3	0	0	1	1	2	2	3	3	1	3	1	0	0	3	2	0	3	0	2	2	1	3	2	3
Cure	0	0	0	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	2	3	2	1	0	2	0	2	0	0	2	

<div> <div>Process Control Quality Planning Spreadsheet</div> <div> Liner Preparation (Baseline: Batch Mix Preliner &amp; Curative)  Liner Application (Baseline: In-Line Catalyst Add/Spray) </div> </div> <div>Page 1 of 4</div>									
Process Feature/Parameter	Control Subject	Goal	Sensor	Recording Method	Measurement Frequency	Sample Size	Criterion	Responsibility	Criticality
Atomizing Air Nozzle Configuration	Component Identification	Required Configuration	N/A	Source or Receiving Inspection	Verify P/N Prior to Each Run	N/A	Configuration Meets Design Rqmt	Quality Assurance	Primary •Thickness
Atomizing Air Nozzle Orientation	Orientation	Horizontal Air Horns	Operator	Pre-Run Process Inspection	Verify Orient Prior to Each Run	N/A	Orientation Horizontal Per API	Operator, Start-Up Input	Primary •Thickness
Atomizing Air Nozzle Pressure	psig	[TBD] psig +/- Tolerance	In-Line Pressure Transducer	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Primary •Thickness
Atomizing Air Temperature	deg F	[TBD] psig +/- Tolerance	In-Line Thermocouple	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Primary •Thickness
Segment Rotation Rate	RPM	[TBD] psig +/- Tolerance	Robot Velocity Control Unit	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Thickness
Density of Ingredients	gm/cc	[TBD] gm/cc +/- Tolerance for each Ingredient	Receiving Lab Analysis	Ingredient Database File	N/A	Material Specification	Material Specification	Operator, Start-Up Input	Possible Influence Only
Fluid Flow Rate (Preliner and Curative)	cc/min	[TBD] cc/min +/- Tolerance	In-Line Flow Meter	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Primary •Thickness •Cure
Fluid Nozzle Configuration	Component Identification	Required Configuration	Operator	Source or Receiving Inspection	Verify P/N Prior to Each Run	N/A	Configuration Meets Design Rqmt	Quality Assurance	Primary •Thickness
Fluid Nozzle Service Life	Configuration Tolerance	No Performance Deterioration	Visual Inspection	Pre-Run Process Inspection	Verify Prior to Each Run	N/A	Configuration Meets Design Rqmt	•Maintenance Plan •Operator	Possible Influence Only
Fluid Pressure at Applicator	psig	[TBD] psig +/- Tolerance	In-Line Pressure Transducer	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Primary •Thickness

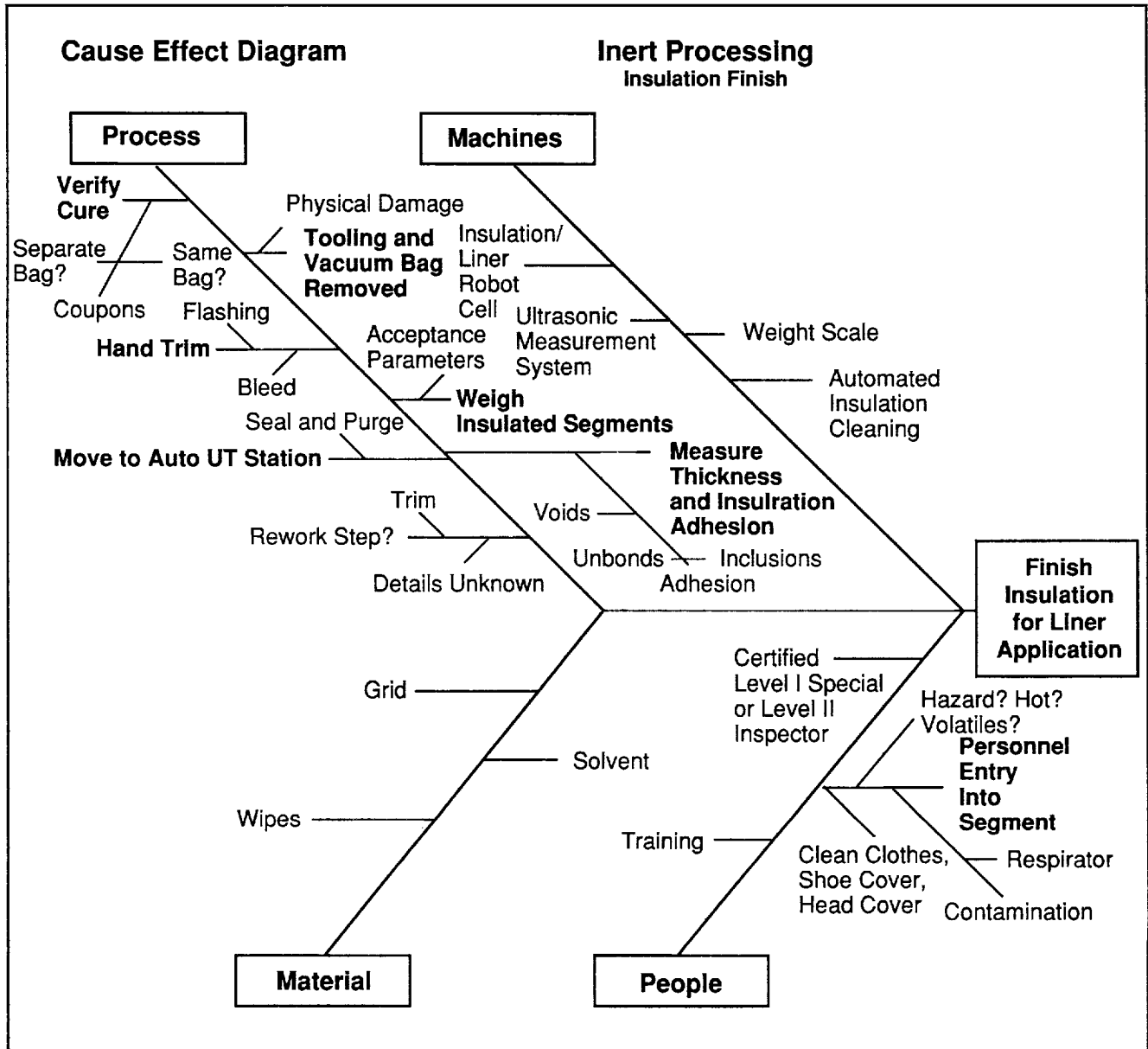
**Process Control Quality Planning Spreadsheet**  
**Liner Preparation (Baseline: Batch Mix Preliner & Curative)**  
**Liner Application (Baseline: In-Line Catalyst Add/Spray)**

Process Feature/ Parameter	Control Subject	Goal	Sensor	Recording Method	Measure- ment Frequency	Sample Size	Criterion	Respon- sibility	Criticality
Fluid Pressure at Pump	psig	[TBD] psig +/- Tolerance	Field Gage	Pre-Run Process Inspection	Verify Prior to Each Run	N/A	Program Control Setting	Operator, Start-Up Input	Possible Influence Only
Applicator Traverse Rate	in/min	[TBD] psig +/- Tolerance	Robot Velocity Control Unit	Data Acquisition System	Continuous Real Time	N/A	Orientation Horizontal Per API	Operator, Start-Up Input	Secondary •Thickness
Liner Viscosity from Batch Mixer	centipoise	[TBD] cp +/- Tolerance	Laboratory Chemical Analysis	Material Acceptance Database	Verify Accept Prior to Each Run	Material Specification	Program Control Setting	Quality Assurance	Secondary •Thickness •Cure
Spray Pattern Width	in	13, minimum	In-Line Thermocouple			N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Thickness
Standoff Distance	in	12, minimum	Robot Velocity Control Unit	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Thickness
Temperature, Pre-Liner and Curative	If ambient, deg F	75 deg F +/- Tolerance	Field Thermometer	Pre-Run Process Inspection	Verify Prior to Each Run	N/A	Program Control Setting	FOperator, Start-Up Input	Possible Influence Only
	If heated, deg F	[TBD] deg f +/- Tolerance	In-Line Thermocouple	Data Acquisition System	Continuous Run Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Thickness •Cure
Viscosity, Pre-Liner	centipoise	[TBD] cp +/- Tolerance	Operator	Source or Receiving Inspection	Verify P/N Prior to Each Run	N/A	Configuration Meets Design Rqmt	Quality Assurance	Primary •Thickness
Temperature, Ingredient Storage	If ambient, deg F	75 deg f +/- Tolerance	Facility Temperature Record	Material Acceptance Database		N/A	Material Specification	Quality Assurance	Secondary •Cure
	If heated, Deg F	[TBD] deg F +/- Tolerance	In-Line Thermocouple	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Cure

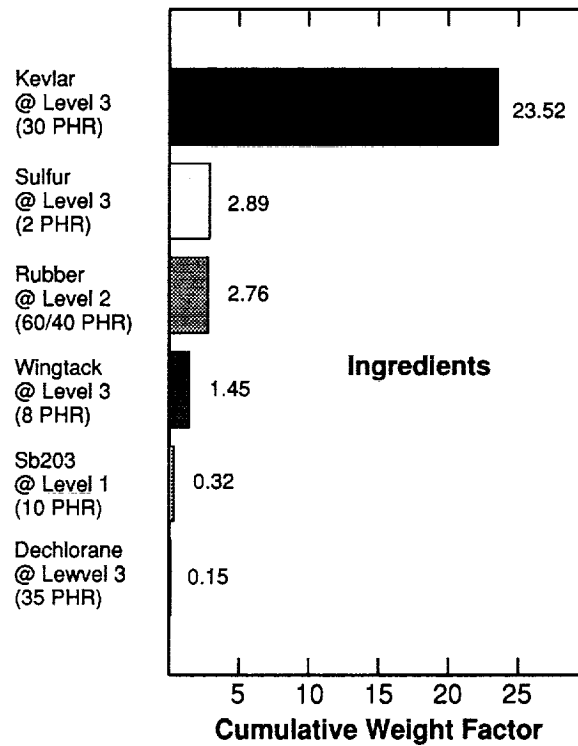
**Process Control Quality Planning Spreadsheet**  
**Liner Preparation (Baseline: Batch Mix Preliner & Curative)**  
**Liner Application (Baseline: In-Line Catalyst Add/Spray)**

Process Feature/ Parameter	Control Subject	Goal	Sensor	Recording Method	Measure- ment Frequency	Sample Size	Criterion	Respon- sibility	Criticality
Moisture, Ingredient Storage	grains H <sub>2</sub> O/ lb air	35 Maximum	Storage Facility Stripchart	API Inspection Point	Verify Prior to Each Run	N/A	Material Specification	Quality Assurance	Secondary •Cure
Shelf Life, Ingredient	Expiration Date	Maximize	Laboratory Chemical Analysis	Material QA Plan	Material Specification	Material Specification	Material Specification	Quality Assurance	Possible Influence Only
Hazards, Handling		Meet All Safety Standards						Environ Affairs & Safety	
Carbon Black Dispersion	RPM and Time	Maximize Dispersion	Mixer Instrumentation	Mix API	Mix API	Mix API	Mix API	Quality Assurance	Secondary •Cure
Pressure, Mix Equip Air Motors	psig and RPM	Thorough Mix	Mixer Instrumentation	Mix API	Mix API	Mix API	Mix API	Quality Assurance	Possible Influence Only
Density, Pre-Liner and Curative	gm/cc	[TBD] gm/cc +/- Tolerance	Laboratory Analysis	Material Specification	Material Specification	Material Specification	Material Specification	Quality Assurance	Primary •Thickness
Vacuum, Pre-Liner Mix Cycle	in Hg	28, Max During Mix Cycle	Mixer Instrumentation	Mix API	Mix API	Mix API	Mix API	Quality Assurance	Possible Influence Only
Metering, Pre-Liner and Curative	cc/min	[TBD] cc/min +/- Tolerance	In-Line Flowmeter	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Primary •Thickness •Cure
Metering, Pre-Liner and Curative	gm/min Verify cc/min Flow	[TBD] gm/min +/- Tolerance	Mix Facility Scales	Mix API	Mix API	Mix API	Mix API	Quality Assurance	Secondary •Thickness •Cure
Metering, Pre-Liner and Curative	Mix Ratio	[TBD] ratio +/- Tolerance	Automated Analysis Calculation	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Thickness •Cure

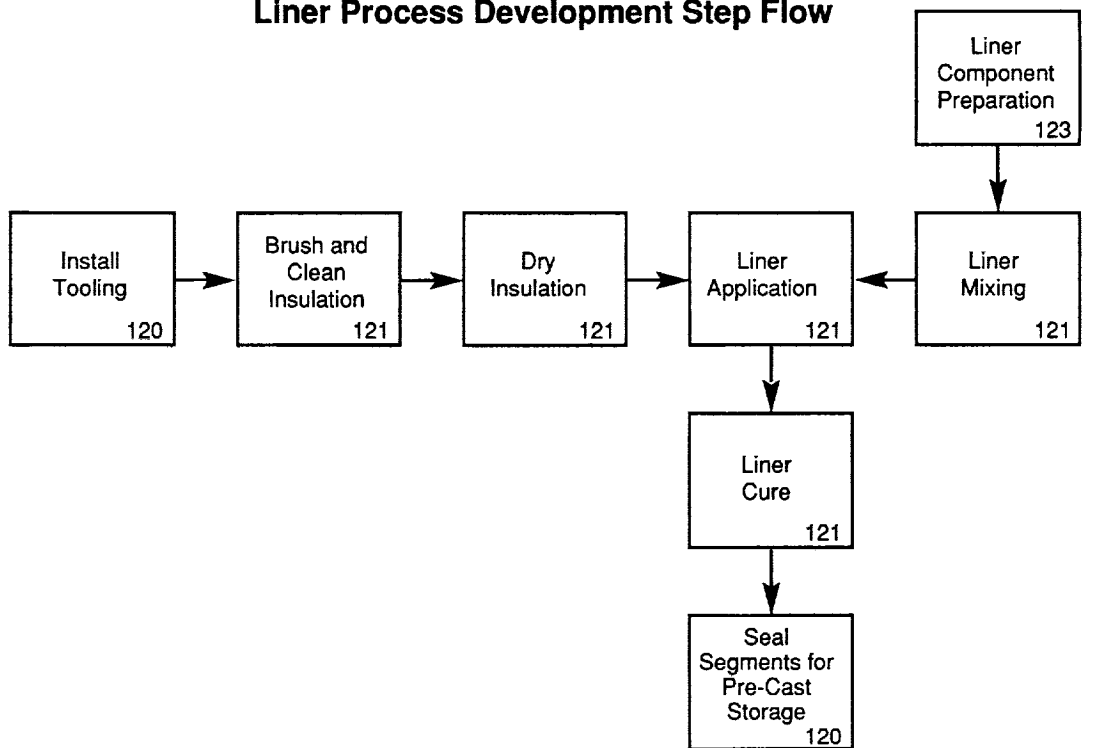
<div> <div>Process Control Quality Planning Spreadsheet</div> <div> Liner Preparation (Baseline: Batch Mix Preliner &amp; Curative)  Liner Application (Baseline: In-Line Catalyst Add/Spray) </div> </div> <div>Page 4 of 4</div>									
Process Feature/Parameter	Control Subject	Goal	Sensor	Recording Method	Measurement Frequency	Sample Size	Criterion	Responsibility	Criticality
Weight of Applied Liner	lbs	[TBD] lbs for Each Specific Segment	Automated Weight vs Surface	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Primary •Thickness
Premix Shelf and Pot Life	Expiration Date	Maximize	Laboratory Chemical Inspection	Pre-Run Process Inspection	Material Specification	Material Specification	Material Specification	Quality Assurance	Possible Influence Only
Temperature, Cure	deg F	135 deg F +/- Tolerance	Cure Facility Instrumentation	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Cure
Humidity, Cure	gm H <sub>2</sub> O/lb air	35, maximum	Cure Facility Instrumentation	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Cure
Time, Cure	hrs	16 hrs, maximum	Cure Facility Instrumentation	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Cure
Air Flow Rate, Cure	CFM	[TBD] cfm +/- Tolerance	Cure Facility Instrumentation	Data Acquisition System	Continuous Real Time	N/A	Program Control Setting	Operator, Start-Up Input	Secondary •Cure
Particulate Contamination	In H <sub>2</sub> O Differential	[TBD] in H <sub>2</sub> O +/- Tolerance	Cure Facility Instrumentation	Facility Maintenance Plan	Facility Maintenance Plan	Facility Maintenance Plan	Facility Maintenance Plan	Facility Maintenance Plan	Possible Influence Only



### Cumulative Weight Factor Distribution of Significant Ingredients



### Liner Process Development Step Flow









## The Herzberg Theory of Job Satisfaction

### Motivators

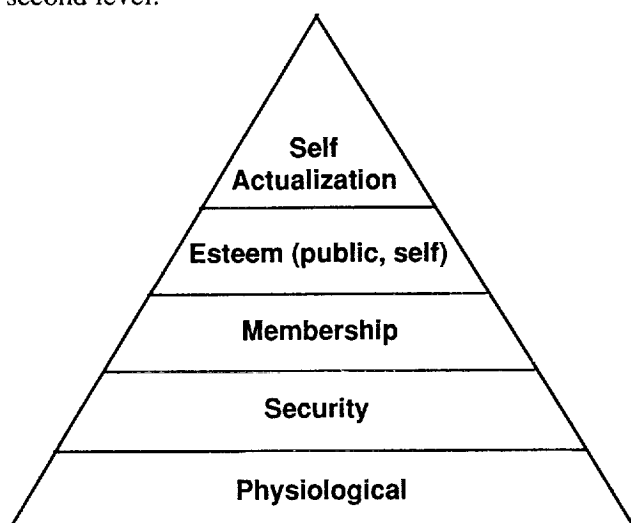
1. Recognition
2. Achievement
3. Possibility of growth
4. Advancement
5. Responsibility
6. Job itself

### Hygienes

1. Working conditions
2. Company policy and administration
3. Interpersonal relationship with supervisor
4. Interpersonal relationship with peers
5. Pay

## Maslow's Hierarchy of Human Needs

Each person goes through the same set of needs in the same order. When one need is met, the individual seeks the next need level. Some go through the hierarchy more rapidly than others. Some never get past the second level.



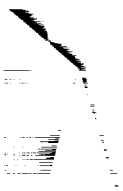
## McGregor's Theory X and Theory Y

The Theory X assumptions about human behavior are as follows:

1. The average human being has an inherent dislike of work and will avoid it if he can.
2. Because of this human characteristic of dislike of work, most people must be coerced, controlled, directed, or threatened with punishment to get them to put forth adequate effort toward the achievement of organizational objectives.
3. The average human being prefers to be directed, wishes to avoid responsibility, has relatively little ambition, and wants security above all.

The Theory Y assumptions are as follows:

1. The expenditure of physical and mental effort in work is as natural as play or rest.
2. External control and threat of punishment are not the only means for bringing about effort toward organizational objectives. Man will exercise self-direction and self-control in the service of objectives to which he is committed.
3. Commitment to objectives is a function of the rewards associated with their achievement.
4. The average human being learns, under proper conditions, not only to accept but to seek out responsibility.
5. The capacity to exercise a relatively high degree of imagination, ingenuity, and creativity in the solution of organizational problems is widely, not narrowly distributed.
6. Under the conditions of modern industrial life, the intellectual potentialities of the average human being are only partially utilized.

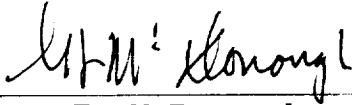


APPROVAL

AN EVALUATION OF THE TOTAL QUALITY MANAGEMENT (TQM)  
IMPLEMENTATION STRATEGY FOR THE ADVANCED  
SOLID ROCKET MOTOR PROJECT  
AT NASA'S MARSHALL SPACE FLIGHT CENTER

By Harry F. Schramm and Kenneth W. Sullivan

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.



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George F. McDonough  
Director, Science & Engineering

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## Report Documentation Page

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7. Author(s)  Harry F. Schramm and Kenneth W. Sullivan		8. Performing Organization Report No.	
		10. Work Unit No.	
9. Performing Organization Name and Address  George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		11. Contract or Grant No.	
		13. Type of Report and Period Covered  Technical Memorandum	
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16. Abstract  This document represents an evaluation of the NASA's Marshall Space Flight Center (MSFC) strategy to implement Total Quality Management (TQM) in the Advanced Solid Rocket Motor (ASRM) Project. The evaluation of the implementation strategy reflected the Civil Service personnel perspective at the project level. The external and internal environments at MSFC were analyzed for their effects on the ASRM TQM strategy. Organizational forms, cultures, management systems, problem solving techniques and training were assessed for their influence on the implementation strategy. The influence of ASRM's effort was assessed relative to its impact on mature projects as well as future projects at MSFC.			
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